Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

WHILE planning this first Aviation Issue of *Instruments*, while assigning authors and even while editing the first three or four articles received, it was easy to conceive an editorial. It was *too* easy! Now, your editor feels as bashful as if he were opening a great congress of Science and Industry. Those brilliant ideas and clever wordings now seem flat and stale. For example the idea of commenting on the relative merits of different developments by different air-lines. As if the air-lines had entered a contest for mere words of praise on the excellence of their instrument work! The truth is that they all have entered a far more serious contest—the only one that counts—where the only prize for excellence is existence itself, where any air-line whose instrument work is not excellent would be grounded by Uncle Sam before you could say "directional gyro caging knob synchronizer pinion longitudinal adjustment sleeve." The truth is that all air-lines are first-prize winners.

And the same goes for all aircraft manufacturers, all engine manufacturers, the whole Aviation Industry.

But how can I "introduce" the contents of this issue?

At last a good idea! I'll let a better man do it!

Because I admire the man who for fifteen years has played an unheralded but vitally important part in developing all phases of aircraft instrumentation—navigational, power-plant, automatic piloting, instrument-landing, ice-warning, meteorological, flight-testing, etc., etc.,

Because I respect the Chief of the Aeronautic Instruments Section at THE Bureau,

Because I'm grateful to a self-starting member of *Instruments'* Editorial Advisory Board,

And because I like "Brom"

I turn over this page to him. —MFB

Scope of Instrumentation in Aeronautics

By W. G. BROMBACHER

Chief, Aeronautic Instruments Section, National Bureau of Standards, Washington

IN the past decade the technically-minded public has largely focused its interest upon the need for aircraft instruments to measure altitude more accurately, upon radio means for making instrument landings, and for measuring ground speed when the ground is not visible.

These are outstanding problems, of which at least the first two are in a fair way to satisfactory solution.

Other instruments with which the aircraft is usually equipped and in which service interest has been great, are those directly or indirectly needed for determining position, also automatic pilots, and oxygen supply equipment—upon which work has been unremitting and consequent improvement has been steady. Position on the earth's surface is determined by celestial observations or dead reckoning or a combination of both. Instruments include octants, drift meters, radio equipment, compasses, airspeed meters and timepieces.

Noteworthy, too, is a recent trend toward power-plant instruments of the electric type, involving intensive engineering activity.

There are, however, types of instruments which interest only a few specialists since they are not commonly used as service instruments. These are test instruments used in flight and on the ground, instruments peculiar to airships, and instrument testing equipment. Much thought has been given to these instruments by the few engineers, scientists and pilots directly interested, but owing to the small number required, developmental work solely with the aeronautic applications in mind, by the engineering staffs of instrument companies, has—with some conspicuous exceptions—been relatively small. In many instances further development is desirable.

Under flight test instruments we may list barographs, CO indicators, engine torque meters, recording tachometers, recording accelerometers, airspeed recorders, suspended-head airspeed meters, free air thermometers and perhaps, since these are possible service instruments, fuel flow meters and exhaust gas analyzers.

For aircraft tests on the ground and in flight, vibration measuring apparatus, stroboscopes and strain meters may be mentioned.

Instruments peculiar to airships include superheatmeters, suspended-head true airspeed meters and others, the need for which depends upon the size and design of the airship.

Special equipment for testing instruments includes much that is commercially available but some items not so available or requiring modification, are mercurial barometers for testing altimeters, tachometer test stands, manometers for various purposes, accelerometer test equipment, oxygen apparatus test equipment, and some special equipment for testing electrical instruments.

It is necessary to mention here instruments primarily of military importance, such as special altimeters and directional means required in aerial photography, and armament instruments such as gunsights and drift sights.

A few aircraft instruments require lubrication. The requirements include operation in the temperature range −50 to +50° C. and higher, which if coupled with necessity of long life in the bearings, is hardly within the capacity of known liquid lubricants. In the past this problem, except for work on lubricants derived from petroleum, has not obtained the attention of lubrication engineers, largely because of the small production quantities involved. More research is needed to find an entirely satisfactory lubricant.

Last of all, mention should be made of the importance of the standardization of fittings and electrical connections wherever possible. Much fine work has been done especially where the instruments themselves are reasonably standard, but the job is obviously never complete. It is prosaic but of the highest importance.

The CAA and Industry Coöperate to Develop Instrumentation

By C. I. STANTON
Deputy Administrator, Civil Aeronautics Administration, Washington

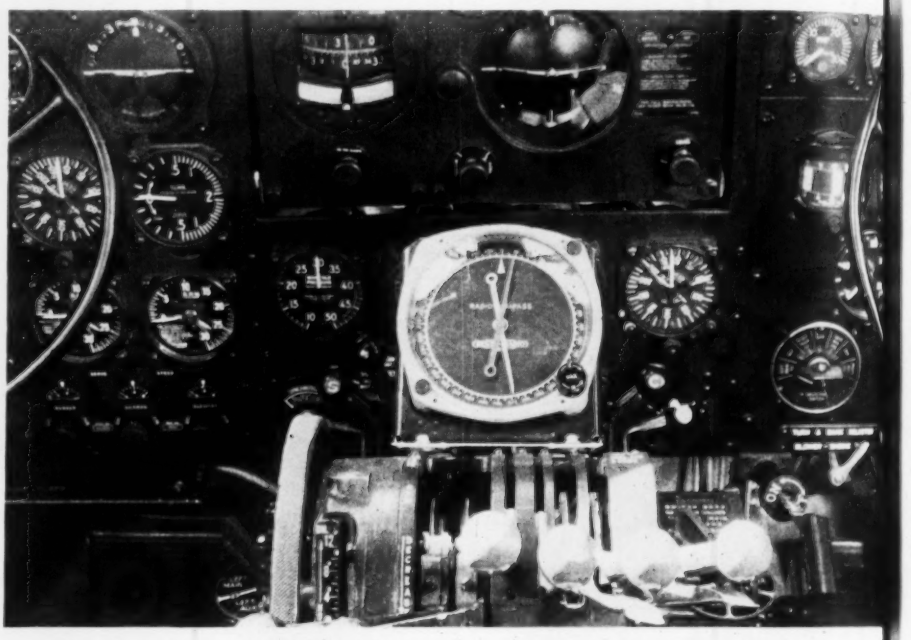
DEVELOPING new instruments to increase the safety of aircraft operation is an important item in the long list of services rendered to aviation by the Civil Aeronautics Administration. A comparatively small staff of CAA workers in this field, working in coöperation with the airlines, equipment manufacturers, Army and Navy, leading universities, and other interested groups, have been responsible for some notable advances in aircraft instrumentation.

DIRECTION FINDER

In the field of radio instrumentation, the accomplishments of CAA engineers have been particularly significant. The dual automatic radio direction finder, perfected during the last three years with the assistance of three manufacturers, is a case in point.

The instrument is actually two radio direction finders interconnected, with their needles operating on the same azimuth scale. The needle of each receiver points to the station on which its receiver is tuned. Thus, when a station ahead and one to the rear are tuned in, the pilot can fly along a straight line between the stations by moving his plane to right or left until the needles form a straight line.

The principle is made clear by stretching a rubber band between two points, considered as stations. By moving the band to right or left anywhere along its length, the relative position of the plane with respect to the stations is revealed. Skilled instrument pilots can work out numerous triangulation and other navigation procedures more rapidly with the new device. It was first installed in the CAA's laboratory plane and is now commercially manufactured, and commencing to be installed by the airlines.



Two-needle direction finder (Bendix make) in a Douglas instrument panel. See also Ray Shrader's article on page 282, where diagrams of the operation are shown.

UHF DEVELOPMENT

The CAA also originated specifications for a new ultra-high-frequency radio receiver which the airlines are now purchasing for use on runs where the CAA has installed UHF (ultra-high-frequency) radio ranges and landing systems. UHF equipment, it is expected, will contribute greatly to safety, since it is not subject to static interference, and static is most prevalent in bad weather, just when the pilot's need for dependable radio guidance is greatest.

The receiver is equipped with push buttons which can be set to 33 selected frequencies between 110 and 132 megacycles, relieving the pilot of any necessity for tuning with knobs. It can receive UHF course signals of the CAA radio range stations and instrument landing localizers, as well as voice instructions from airport traffic control towers.

INSTRUMENT LANDING SYSTEM

UHF radio ranges are now operated by the CAA along the New York-Chicago airway, and other installations are under way, with the ultimate goal conversion of the entire 35,000 miles of airways. Airports have been ordered by the Federal Communications Commission, acting with the advice of the CAA, to install UHF transmission equipment for traffic control by 1942. Instrument landing systems run on UHF are in existence at Indianapolis, and being installed by the CAA at Oakland, California, and Washington, D. C., with six more in process of manufacture and due to be installed at Chicago, Cleveland, Fort Worth, Kansas City, Los Angeles and New York.

These landing systems are in themselves a triumph in aircraft instrumentation, culminating experiments which began back in 1928. One simple dial enables the pilot to see at a glance whether he is taking the proper course for a landing, even though the airport may be enveloped in fog.

The system devised and now being installed by the CAA meets the specifications of the Radio Technical Commission for Aeronautics, an impartial body representing the airlines, the military services, scientific institutions, radio manufacturers, and government agencies. It incorporates the best features of several experimental systems submitted to the RTCA. It is operated by radio and consists of four fundamental elements:

(1) A runway localizer which provides a range course for lateral guidance;

(2) a glide path which provides a means for descent;

(3 and 4) two vertical marker beacons to indicate the progress of approach to the landing field.

The effect of the localizer beam radio transmission is to provide an imaginary vertical plane extending along the center line of the runway in the direction of approach. A pointer on an instrument before the pilot remains in a vertical position as long as the airplane is in this imaginary plane. If the airplane deviates to the right, the pointer swings to the left and the pilot must turn his craft to the left until the pointer swings back to the vertical. Exactly the opposite occurs if the aircraft deviates to the left. The effect of the glide path radio transmission is to provide a surface* inclining away from the approach end of the runway at an angle of 3° to 4° from the earth's surface. (At about 5 miles from the end of the runway the glide path is approximately 1,500 feet above the ground).

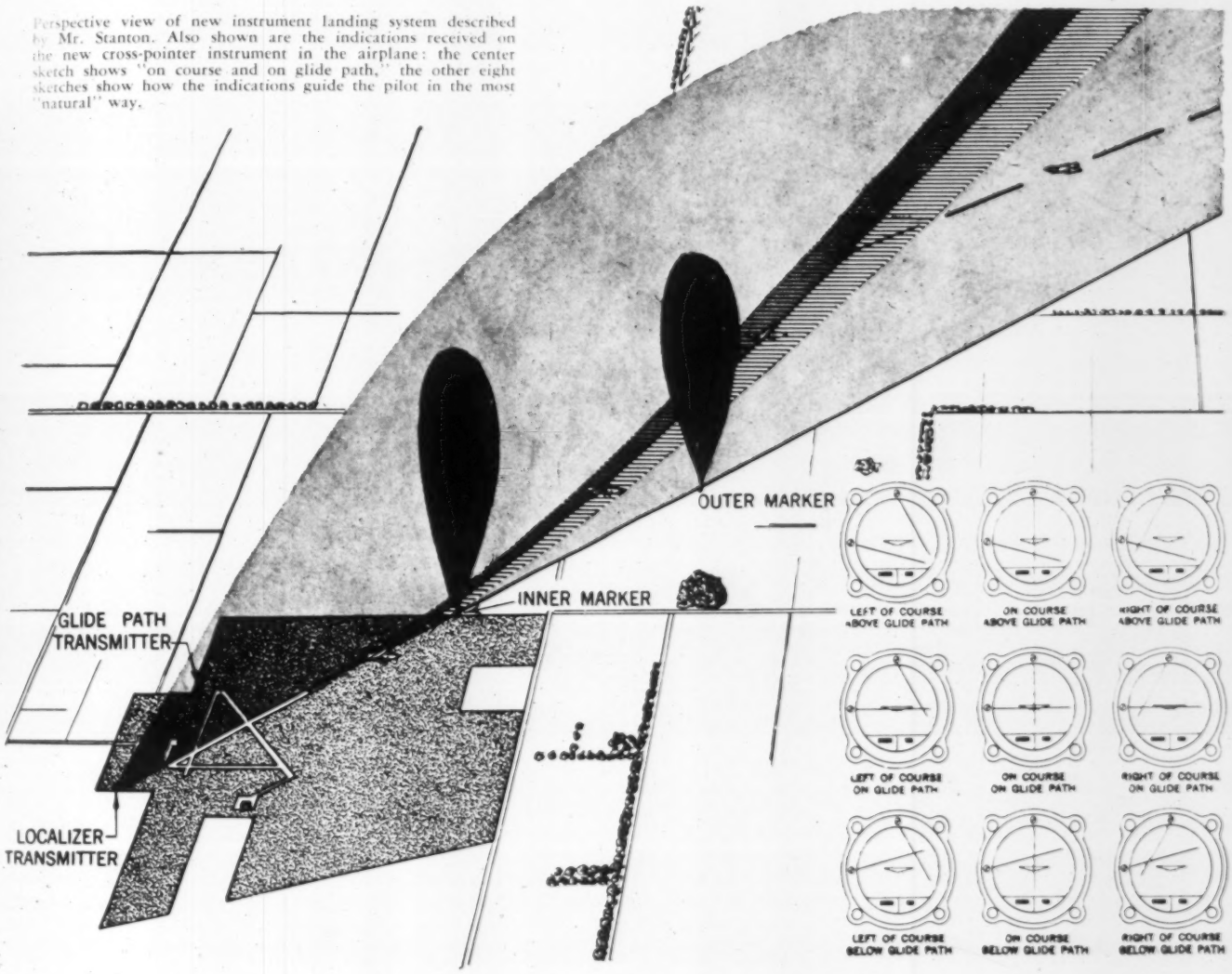
*Actually, the glide path is formed by a portion of a curved surface; however, the portion utilized for the approach is relatively straight and, for the purpose of a simplified explanation, may be thought of as a narrow inclined surface, curved slightly at the bottom to meet the runway at a gentle angle.

A horizontal needle, crossing the vertical pointer mentioned previously, tells the pilot whether the aircraft is flying above or below, or directly along the imaginary inclined surface. If this needle falls below the horizontal the pilot must descend to intercept the glide path and, conversely, if the needle swings above the horizontal the pilot must climb to regain the glide path.

The intersection of these two imaginary surfaces provides an imaginary line which inclines at a gentle angle upwards from the end of the runway for many miles. By means of the pointer and needle indications already described the pilot can fly his aircraft downward along this imaginary line with a high degree of precision. But the automatic instrumentation provides even more information when the pilot approaches the airport and the runway:

(1) The radio marker beams are directed upward and the signals fill a fan-shaped space intersecting the localizer beam and crossing the glide path. The outer marker is about two miles from the airport and intercepts the glide path at a point where it is 510 feet from the ground. The inner marker is located at the boundary of the field in line with the runway and intercepts the glide path at an altitude of 45 feet. Flying over the *outer* marker causes a *purple* light to flash on the aircraft's instrument panel at a rate of two dashes per second for a period of eight seconds, while at the same time a characteristic audible signal is transmitted and received by the pilot through his headphones. The *inner* marker flashes a *yellow* light at a rate of six dots per second for approximately 1½ seconds, and provides an audible signal plainly distinguishable from that of the outer marker.

(2) At the bottom of the instrument faces there is a sector split in the middle with green on the left and red on the right. The chart used by the pilot is tinted red in the area to the left of the localizer beam and green to the right. Thus, whenever the vertical pointer is in the green sector the pilot knows he is in the green area indicated on the chart, and if the pointer is in the red sector he can be sure he is in the red area of the chart, regardless of the heading of the ship.


OUTER MARKER
INNER MARKER
GLIDE PATH TRANSMITTER
LOCALIZER TRANSMITTER
LEFT OF COURSE ABOVE GLIDE PATH
ON COURSE ABOVE GLIDE PATH
RIGHT OF COURSE ABOVE GLIDE PATH
LEFT OF COURSE ON GLIDE PATH
ON COURSE ON GLIDE PATH
RIGHT OF COURSE ON GLIDE PATH
LEFT OF COURSE BELOW GLIDE PATH
ON COURSE BELOW GLIDE PATH
RIGHT OF COURSE BELOW GLIDE PATH

Perspective view of new instrument landing system described by Mr. Stanton. Also shown are the indications received on the new cross-pointer instrument in the airplane: the center sketch shows "on course and on glide path," the other eight sketches show how the indications guide the pilot in the most "natural" way.

OTHER DEVELOPMENTS

Another interesting development is automatic monitors for low-frequency radio ranges and fan markers. Experimental equipment now being manufactured for service testing is designed to go into action when the range signal deviates from the true course, adding a string of X's to the signal as a warning to the pilot, and setting off a siren and red light in the range station and the airline dispatcher's office. The siren may be turned off, but the red light and X's remain on until the range signal returns to true course. The other monitor acts similarly when the fan marker signal reaches a dangerously low volume.

Instruments developed by the C.A.A. to measure flutter and vibration characteristics of aircraft are now being given ground and flight tests at the Indianapolis experiment station of the C.A.A. The advent of larger and faster aircraft gives special importance to these studies.

Other devices on which C.A.A. technical men are working include a stall warning indicator, an automatic instrument log using infra-red film, and equipment for field inspection of aircraft fabric. In the study stage is a broad project aimed at the development of instruments for the private pilot, which can be sold at a moderate price without sacrificing dependability.

A General Consideration of Aircraft Instruments

By ALEXANDER KLEMIN
Guggenheim Research Professor, College of Engineering, New York University

IT is the purpose of this article to indicate briefly how the airplane designer and aviation people generally are apt to regard aircraft instruments, and what they are likely to demand. Some of the remarks apply to aircraft instruments as a whole, some to specific classes. It is hoped that the article will serve as an introduction to the more detailed writings of others in this issue of *Instruments*.

I. General Requirements

The general requirements in regard to aircraft instruments to which aviation people might be expected to subscribe might be presented somewhat as follows:

1. *Aerodynamic Resistance.*

The higher the speed of the airplane, the more important it becomes to cut down unnecessary aerodynamic resistance. Even a Pitot tube mounted on a tube four feet ahead of the leading edge has a resistance which counts. An exposed Venturi to supply power to an air-driven instrument such as a gyroscopic bank and turn indicator involves an appreciable waste of power because the aerodynamic resistance involves a loss of perhaps fifty times the power delivered to the instrument.

2. *Light Weight.*

Instruments for the airplane must be much lighter than anything permissible in land vehicles. Civil engineers often make excellent stress analysts of the airplane but it takes them a year or two of practice to realize that an airplane spar must be in appearance and weight fragile in comparison with a bridge girder. An automobile engine weighs five or six times as much in pounds per horsepower as an airplane engine. The skilled aircraft instrument designer must watch every ounce of weight.

3. *Compactness.*

The aircraft instrument must combine with accuracy not only light weight but also compactness. Bulky instruments will crowd the dashboard; they may be too bulky even for installation behind the dashboard.

4. *Simplicity of Installation and Repair.*

The strength of an air force is not measured by the number of planes in the hangars but by the number of planes capable of taking the air at a few minutes' notice. The number of skilled mechanics cannot be increased indefinitely. The advantage of simplicity of installation and repair becomes obvious.

5. *Ability to Withstand Many Times The Acceleration Of Gravity.*

The hardiest test pilot in the prime of manhood is apt to lose consciousness when coming out of a dive because of the tremendous centrifugal accelerations encountered, sometimes over eight times the acceleration of gravity. The instrument has no consciousness to lose but it must be able to withstand the highest load factors ever likely to be imposed.

6. *Damping After Oscillation.*

We shall discuss vibration requirements in our next paragraph. In the automobile and other vehicles vibration is of common occurrence. But no other vehicles are subjected to such maneuvers as looping or spinning. There is nothing that will completely prevent oscillation of the instrument indicators under such circumstances but the damping after oscillation should be rapid and reliable. In the case of some instruments it is even possible and desirable to seek insensitivity to acceleration or maneuver.

7. *Freedom From Effects Of Vibration.*

By rubber insulation of the engine mount, vibration in the modern airplane has been greatly diminished. But if a relatively small single-seater fighter is equipped with a 2000-horsepower engine, it is inconceivable that all vibration troubles could be eliminated, even if there is careful insulation of the instrument panel as well as of the mount. Therefore airplane people demand and should be able to obtain instruments that can withstand some degree of vibration indefinitely without loss of accuracy.

8. *Dials For Easy Grouping.*

It is not easy to say whether the airplane designer or the instrument manufacturer should be responsible for the arrangement of the panel so that the pilot can readily survey all instruments and so that related instruments may be placed close together. The best results are achieved by collaboration of technicians in the two categories. But it should be the task of the instrument designer to provide the best possible indicating dials for such purposes—whether by having vertical scales instead of circular scales, or by having all dials of the same size, etc., is not for us to say.

9. *Lighting.*

If a cockpit has to be brilliantly lit, the contrast with the outer darkness becomes quite fatiguing for the pilot and he is apt to lose his judgment of distances in landing. Therefore either idals must be self-illuminating by means of fluorescent paints, or else they must lend themselves to indirect lighting.

10. *Reduction In The Number of Instruments.*

In the early days of flying a cockpit in which there were available an airspeed indicator and an altimeter was considered well equipped. Today the number of instruments which face the pilot is formidable. It is easy to provide a device that will show whether the landing gear is up or down, or how many degrees a flap is deflected. But each such device gives the pilot just that much more instrumentation to watch. It should now be the task of the instrument designer to devise instruments in which one indicator will be the equivalent of two or three; or in which several indications are projected on a small space; or in some other manner to alleviate the pilot's task. Several attempts along these lines have already been successful.

11. *Other Requirements.*

Accuracy goes without saying, but accuracy must be combined with all the other characteristics. At least in an open-cockpit machine or a single-seater intended for high-altitude work, instruments must be able to withstand marked changes in temperature. In seaplane work corrosion has to be avoided.

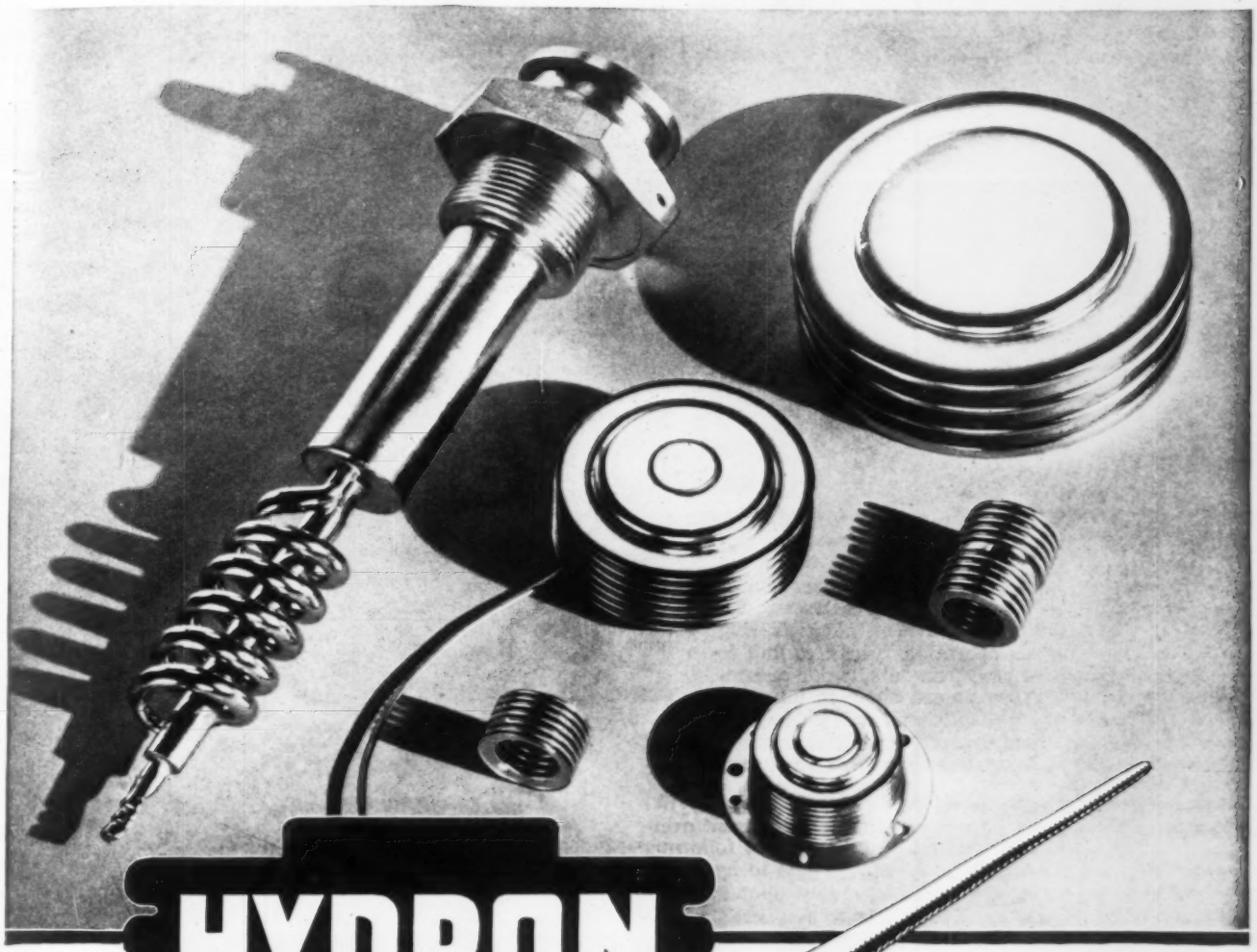
II. Certain Specific Problems

It will be agreed that the general requirements of aircraft instrumentation are comprehensive and not easy to meet in combination. To discuss here the specific requirements of every instrument on board an airplane is impossible. But it may be of interest to discuss briefly certain specific problems or improvements which appear of importance in modern aviation.

1. *An Altimeter Independent of Atmospheric Conditions*

The aircraft altimeter is only an aneroid barometer measuring pressure and a pressure indicator is not a true altitude indicator unless the atmosphere at a particular instant is behaving in exact accordance with the hypothetical "Standard Atmosphere" of the United States. An elaborate system of correction for temperature and pressure variations has grown up and the combination of radio communication and sensitive, adjustable altimeters has achieved highly practical results. Still there remains the need of a practical height indicator totally independent of atmospheric variation. There have been assayed various forms of acoustic altimeters (dependent on the time taken for a sound to be reflected from the ground) and various

(Continued on page 311)



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Instrument Work Innovations

By CARL NISBET
Foreman, Instrument Overhaul Shop, Delta Air Corp., Atlanta, Ga.

Fig.1

COMPLYING with the brief request sent to all air-lines by the editor of *Instruments* in August, we submitted an equally brief outline of Delta's instrument activities. We were rather pleased that he rejected it—because he made a definite request for individual topics, evidently considering these phases of Delta's operations worth calling to the attention of instrument men outside our organization. Delta has already passed along to all other air-lines the results of some innovations. Now we take this opportunity to present a fairly complete list; and to have it reach the instrument men in all industries.

(1) Impressing instrument overhaul men with the importance of their work. Every man in the instrument overhaul department in turn goes riding on test hops following overhauls. Every man in the department gets to fly across Delta routes during bad weather when the pilot must fly blind and rely entirely upon his instruments. The practice of sending all the instrument personnel on the test runs permits each man to observe and understand the operation of the instruments in the airplanes, to note how flight conditions affect the dynamic characteristics of instruments, etc.

(2) Undivided Responsibility. Not only does each man appreciate the importance of instruments but he is made to realize the importance of his own work. Delta's practice is to have each instrument job done by one man from start to finish instead of dividing up the job. One man climbs into the forward baggage compartment or "nose" of the ship, where he has access to the rear of the instrument panel; he inspects the installation and verifies its correctness; he removes the instrument; he carries it (and accessory parts when necessary) to his own bench; he disassembles it; he cleans it and does whatever repair or replacement work is required; he reassembles it and tests it; and finally it is this same man who re-installs that particular instrument with as much care as he exercised at his own bench.

(3) Ground-station Barometers. Delta Air Lines has been unusually successful in minimizing the error of its altimeters by installing ultra-sensitive aneroid barometers at all ground stations and devising a simple method for checking these daily against mercurial barometers.

Back in 1936, Delta, like other air-lines, relied entirely upon the barometric readings of the local weather bureaus. Our station men obtained reports from the weather bureaus in their communities, and this reading was furnished Delta pilots when they radioed in prior to landing. With this barometric reading, the pilot sets his sensitive altimeter, and he is able to read off his height, a most important figure during an instrument landing. That is the theory. In practice there are sources of error. For example, the information was sometimes obtained from a bureau located off the airport, perhaps several stories high. Then, too, it was not generally feasible to obtain timely, up-to-the-minute, information from the local weather bureaus as *each* ship approached the airport. As the reader knows, atmospheric pressure is always changing.

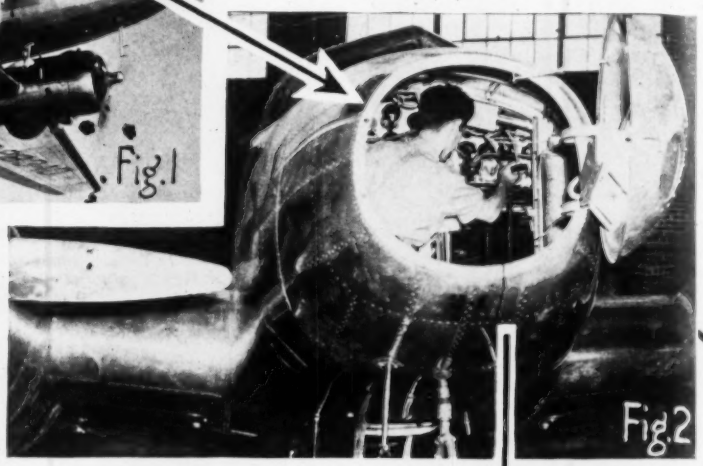


Fig.2

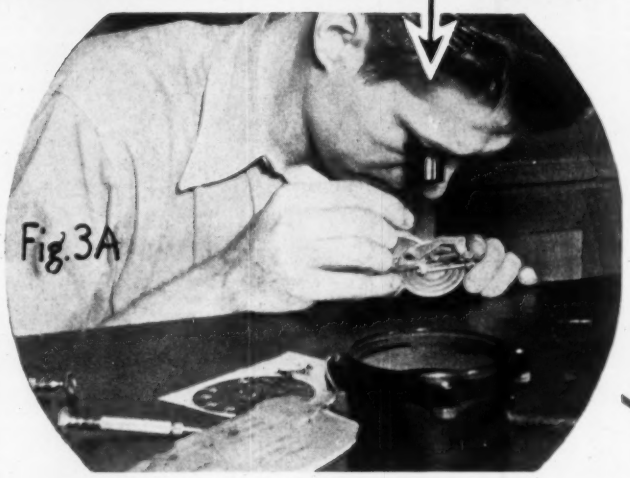


Fig.3A

The solution to the problem clearly was to devise a method by which the men at *each* ground station along the route could take last-minute barometer readings to plus or minus a thousandth of an inch of mercury column—and to do this quickly, immediately preceding the landing of each ship. It was not practical to use mercury barometers in each ground station, because of the expense and because of the difficulty radio operators and station personnel might have in using mercury barometers.

Walter Hendrix, foreman of Delta's instrument shop at that time and now with Boeing in Seattle, devised a method calling for the use of Paulin barometers and of mercurial barometers. The Paulin barometer is a null-method instrument like a laboratory equal-beam balance or a potentiometer. It can be made *sensitive* enough to detect a variation of atmospheric pressure corresponding to a few inches of altitude but—like a laboratory balance whose accuracy depends on that of the weights, or like a potentiometer whose accuracy depends on that of the standard cell—it has to be calibrated by reference to a primary standard, which is the standard mercurial barometer.

We concluded, after a series of experiments in the shop, that it would be possible to reduce the error of altimeters to about ten feet by using Paulin barometers with proper checks. First results were not as promising as we had ex-

ected. More work remained to be done. We found it necessary to visit each of our ground stations along our routes, spending several days at each point. We checked with the local weather bureaus and then took our own mercurial barometer readings at the actual elevations of the most-used sections of the runways at the airport. We compared our airport readings with the readings of the weather bureau, and the difference was the established correction for that station.

If an error of as much as 20 feet is noted when the Paulin barometer is corrected daily against the mercurial barometer, our department is notified immediately and we take quick steps to locate the error, usually substituting a spare barometer while we check the one in error.

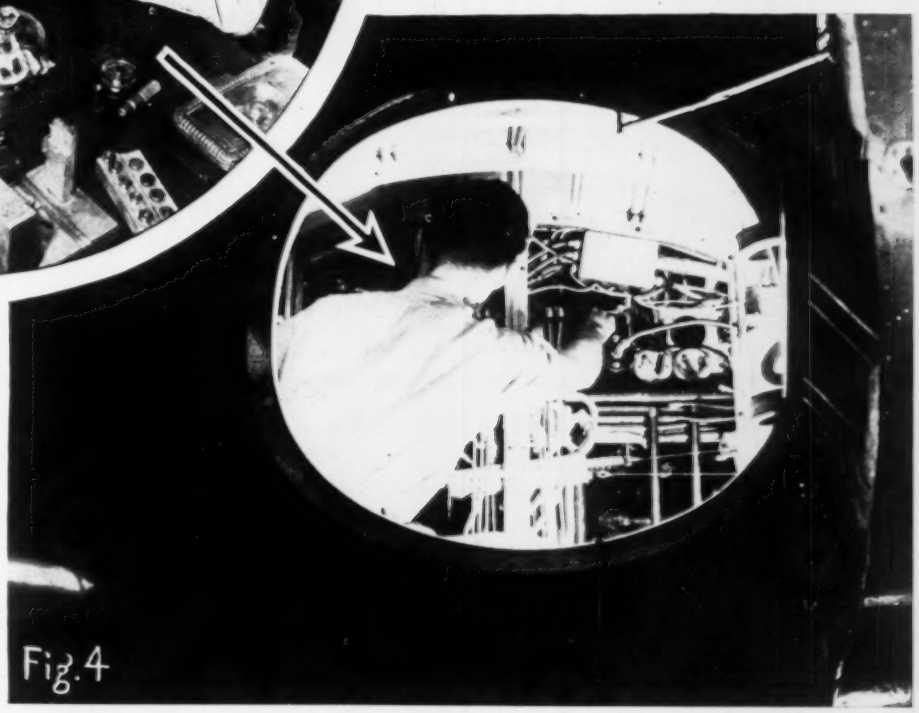
Before fully accepting the system thus devised, we kept close checks for a period of one year. Each pilot had to fill out written reports stating the error noted in his sensitive altimeter at *each* station.

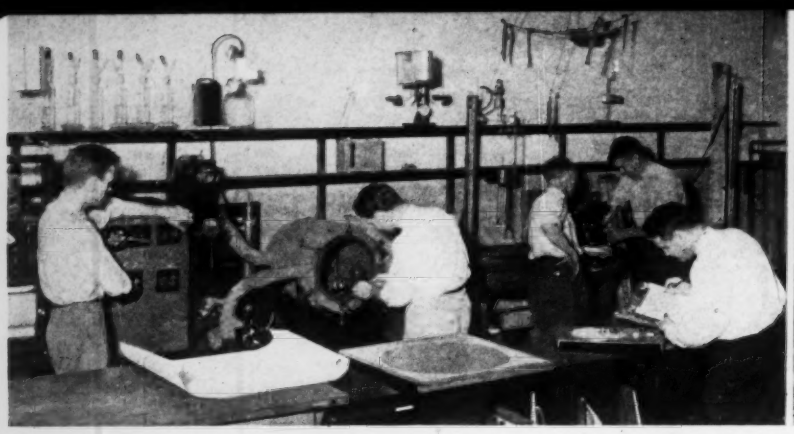
During the period of experimentation, Mr. Hendrix corresponded with Dr. W. G. Brombacher of the National Bureau of Standards, the Kollsman Instrument Co. and the Pioneer Instrument Co. All were most helpful.

For four years now, our altimeter errors have averaged about 20 feet, using the new system, as compared with about 100 feet under the old method. We have cheerfully passed along the benefit of our experience to other air-lines interested, and I am told that they are getting equally accurate results.

The author checks four station Paulins against a Standard

(4) Do watch-makers and jewelers make the best aircraft instrument men? Most answers have been based on imperfect observations of too few men, hired at different times. William Stevens (another veteran Delta instrument man) and I, after instructing national defense workers for eight months, are in a position to give an answer based on a sufficiently large number of individuals all of whom were observed under uniform conditions. Mr. Stevens and I are instructors four night a week in two classes of 52 students learning the airplane instrument repair trade to qualify for civil service positions. The classes are sponsored by the Federal Security Agency, U. S. Office of Education, and the War Department—one of the few such schools in the United States. The course runs six months. We discovered that watchmakers and jewelers did not *necessarily* make good airplane instrument men. In numerous cases the best students were persons who had never handled small tools or worked on instruments of any type.





LEFT—Calibration of an airplane barograph in the M.I.T. Instrument Laboratory. Dr. Draper at right. RIGHT—A staff conference. Instructor Keily explains dynamic temperature errors in radio-meteorograph data while Professors Draper and McKay discuss aircraft compass problems with Mechanician Ashworth. *Standing* (l. to r.): D. P. Keily, Instructor in charge of meteorological instruments; Dr. Draper; Walter McKay, Assistant Professor in charge of aeronautical instruments; Harry Ashworth, Mechanician in charge of instrument construction. *At the table* (l. to r.): Dr. E. P. Bentley, Project Engineer on special instruments; P. J. Chenery and R. C. Seamans Jr., Laboratory Assistants; H. R. Oldfield Jr., Instructor in charge of Vibration Measurements Laboratory.

Instrument Instruction at M. I. T.

By C. S. DRAPER

Professor of Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

INSTRUMENT teaching at the Massachusetts Institute of Technology has developed from a single brief course given by Professor W. G. Brown in 1928 to its present status as a separate division of the Aeronautical Engineering Department devoted entirely to instruction and research in this field. When Professor Brown left the Institute in 1932, his work was taken over by the author of this article. A course on meteorological instruments which had been started by Doctor K. O. Lange was added to the already existing aeronautical instrument work in 1936, and in 1938 the list was increased by the addition of a course on vibration measuring instruments. The material for this course was based on experience gained by the writer and G. P. Bentley during the development of vibration measuring equipment for the U. S. Navy. Various other projects carried out by members of the Instrument Division staff for government agencies and civilian organizations increased the available background of theoretical and practical instrument knowledge.

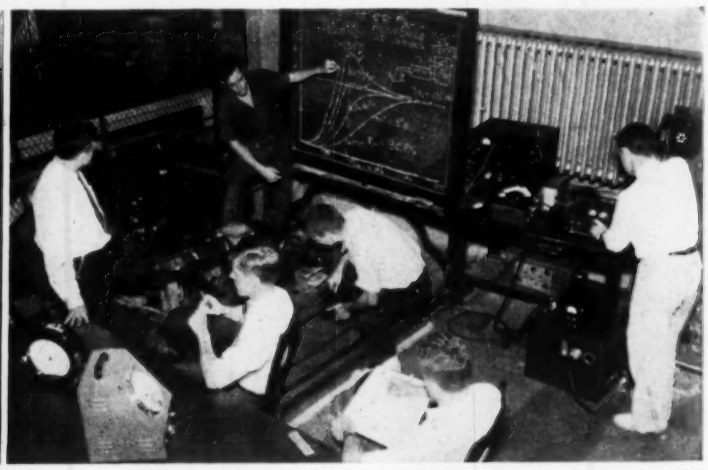
This continuous study of instrument problems has resulted in the development of a generalized system of instrument analysis which can be applied to a wide range of practical cases. An article entitled "General Principles of Instrument Analysis" by C. S. Draper and G. V. Schliestett dealing with certain phases of the general scheme appeared in the May 1939 issue of *Instruments*.

At the present time the Instrument Division staff consists of one professor, two assistant professors, two instructors, two assistants, one master instrument maker, a number of engineers assigned to special projects, and several shop mechanics.

The instruction offered deals with theory and design except for one course on the use and maintenance of meteorological instruments and various short courses especially adapted for students in national defense work. Students are introduced to instruments by means of a lecture course on the basic principles of analysis accompanied by correlated laboratory work. Emphasis is placed on the dynamic aspects of instrument performance. Specialized applications of the basic theory are studied in continuation courses on aeronautical instruments, meteorological instruments, vibration measuring instruments and gyroscopic instruments. The related subject of automatic control is presented in a course given by Professor G. S. Brown of the Electrical Engineering Department.

The basic course attracts from forty to fifty students, aeronautical instruments about twenty-five, meteorological instruments sixty to 120, vibration measuring instruments about twenty-five and gyroscopic instruments (this is a course given only to officers of the military services) about ten. In addition to the regular courses the Instrument Division staff presents defense training courses for Naval men, practicing engineers and civil aeronautics students which add up to between eighty and a hundred individuals.

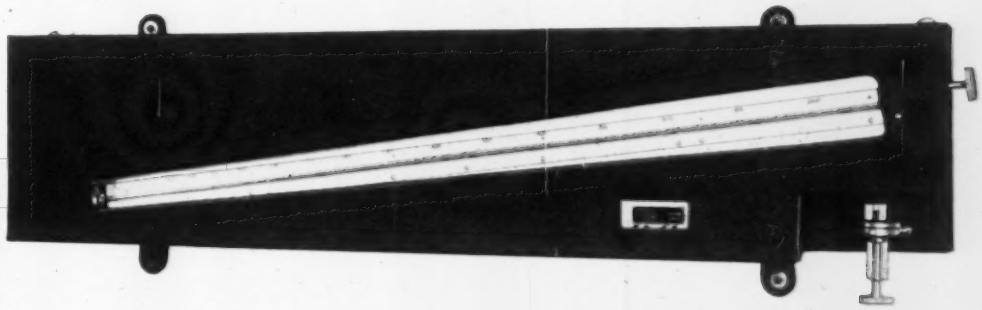
A number of M.I.T. graduates have based their professional jobs on information gained from the instrument courses. The majority of these men are employed by companies connected with aircraft, but a few are connected with industrial instrument concerns. Experience has shown that men interested in the field of instruments are well repaid for time spent on this subject. It is expected that an increasing number of students will thus prepare for their careers.

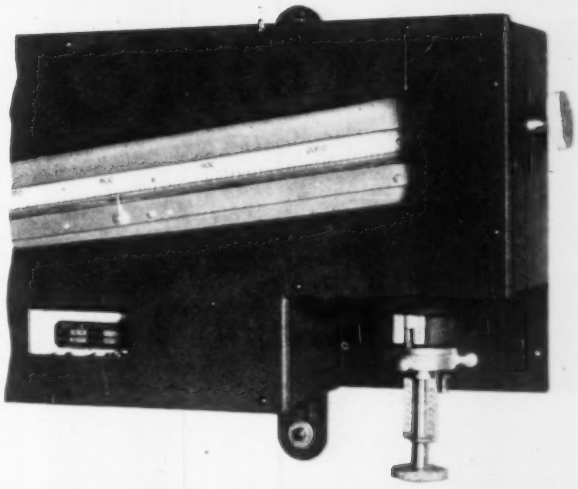


Vibrometers: (LEFT) Vibration Measurements Section and (RIGHT) investigating the performance of a new experimental vibrometer.

The Inclinometer

Another example of MERIAM service to industry





● Complete with 14 different scales that make each instrument practically 14 instruments in 1, temperature and barometric compensators, a ground straight edge for support of the inclined tube, and many other features, Meriam Inclinometers insure the exceedingly accurate measurement—directly in standard flow units—of the air consumed by aircraft engines under test.

Meriam Inclinometers are widely used by practically every prominent aircraft manufacturer for laboratory and production testing. They meet every requirement of the engineers who asked Meriam to build a precision indicating instrument suitable for this exacting work.

Few people will ever need, or perhaps even see an inclinometer, but the same skillful manufacture, the careful attention to minute detail, the dependability, and durability that suggested Meriam instinctively as the logical builder of this exact testing instrument, is available in the more standard types of Meriam manometers, meters and gauges. They are meeting daily, the requirements of thousands of different industrial operations.

Standardize on Meriam instruments for pressure, vacuum, and flow measuring problems requiring liquid column indicating instruments. Our engineers will be glad to cooperate and offer suggestions. Literature descriptive of U-Type Manometers, Well Type Manometers, Vertical and Inclined Tube Flow Meters, Mercury Pressure Gauges, Tank Liquid Level Gauges and other instruments sent on request.

Manometers, Meters and Gauges for the accurate measurement of Pressures, Vacuums and Flows of Liquids and Gases.

THE MERIAM CO.
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Calibrating Vibration-measuring Instruments over a 30-to-1 Frequency Range

By JOHN M. WHITMORE

Head of Elec. & Vibr. Eqpt. Div. of Exp'l Dept., Allison Div. of Gen. Motors Corp., Indianapolis

PRESENT-DAY trends toward lighter and more powerful aircraft engines make it essential for the design engineer to know how efficiently he is using each pound of metal. This knowledge is obtained more quickly and efficiently by proper instrumentation; consequently, the demand for more and better instrumentation has been steadily increasing. Many problems arise in the instrumentation required in obtaining specific items of information, but one problem remains common to all: *proper calibration*.

Calibration problems are as varied as instrument types. The particular instruments of concern are the seismic and the electrically-indicating velocity type for measuring both linear and torsional vibration. Calibration of these instruments consists in determining the electrical output over the complete expected operating range of frequencies and amplitudes. The effects of temperature and motion at right angles to the direction of measurement must be considered in linear units, while temperature and unbalance must be considered in torsional units. If accurate and dependable results are to be expected, great care must be exercised in determining these factors of calibration. Minor damage to pick-ups often changes the amplitude or frequency response as much as 30% and the damage may not be apparent by visual inspection. This necessitates periodic checks of the frequency response.

There are various methods of calibration, but the actual vibration of the pick-up unit through known amplitudes is basic. Frequency response, particularly at the higher frequencies, is sometimes obtained by introducing magnetic fields into the unit, but sizable inaccuracies may be introduced by the unknown response of the added field.

The calibration method which probably is the most widely-used takes advantage of excitation by means of cams and universal joints driven by an electric motor. These excitation methods have proved satisfactory up to 100 c.p.s., but, in general, are not satisfactory above 125 c.p.s. In cases where it is not desired to measure above 100 c.p.s., it is unnecessary to calibrate beyond that point, but the writer finds numerous occasions where vibration up to 300 c.p.s. must be measured. In such cases it is unwise to depend on the continued linear frequency response of the unit beyond the frequencies investigated. This is indicated in the curves presented in this article. It was with this extended range of calibration (10 to 300 c.p.s.) in mind that the units herein described were designed and built.

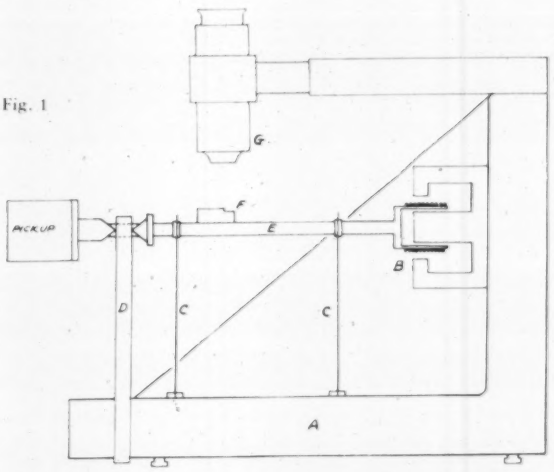
The force required to produce force vibration at 300 c.p.s. in a linear pick-up and its holder is excessive for desirable working conditions.

In the case of torsional pick-up units, a motor speed of 9000 r.p.m. and an extremely heavy, rugged system would be required to insure accurate results. Even if the system were sufficiently rugged, it would be undesirable to turn most pick-up units at 9000 r.p.m.; consequently, in calibrations above 100 c.p.s., it is only natural to turn to systems of resonant vibration.

Fig. 1 is a simplified diagram of a system for producing linear vibration in which resonance is incorporated. Base *A* is a 200-lb. cast iron angle, rigid enough to be used considerably beyond the 300 c.p.s. limit, and with integral braces on each side to prevent bending. The source of force for vibrating the pick-up unit is a permanent-magnet loudspeaker unit *B*, capable of carrying 50 watts, with its moving coil fastened to connecting rod *E*. The moving coil, pick-up unit, and connecting rod are carried by flat parallel springs *C*. These springs were designed to obtain a natural frequency of 10 c.p.s. and, at the same time, to hold the moving coil in the proper position. The system, thus far described, will produce 0.020" total motion up to 50 c.p.s. with a four-ounce unit. Above this frequency, it is necessary to resonate the system by means of the tuning bar *D*. A series of tuning bars permits a complete calibration up to 400 c.p.s. at 0.010" total motion. The bars are held rigidly to base *A* and are clamped to the pick-up driving rod *E* by means of knife edges. This is to prevent the pick-up from going into vibration at right angles to the direction desired. This unit is powered by a 50-watt booster amplifier and a beat frequency oscillator.

To obtain accurate calibration, it is necessary to be able to measure the vibration accurately as well as to produce it. This proved to be somewhat of a problem, but was solved by use of a magnified direct-reading system. A mechanism for producing a line of light was attached to the vibration body, and the band width of the vibrating line was measured by a calibrated microscope. Fig. 3 shows this set-up diagramatically. A Bakelite block *A*, 1" long and ¼" square, completely encloses a 3-volt, 2-amp. light except for a small opening limited by the edge of a razor blade *B*. The only light that can be seen at right angles to the length of this block is that which reflects from the edge of the razor blade. With proper honing of the blade, this line of light

Fig. 1



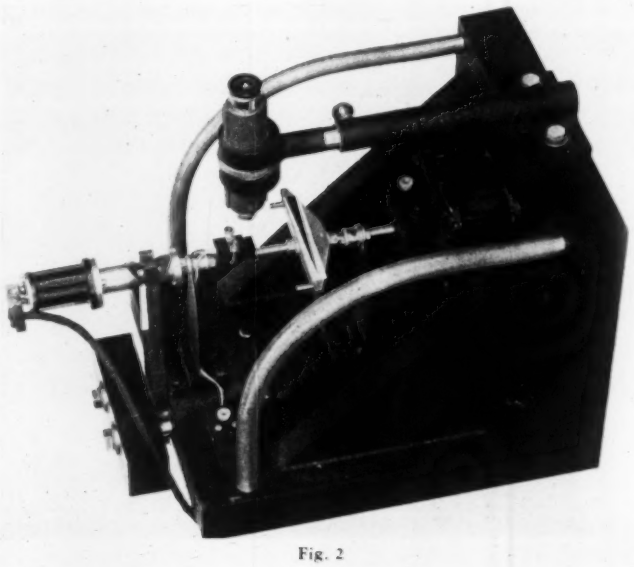
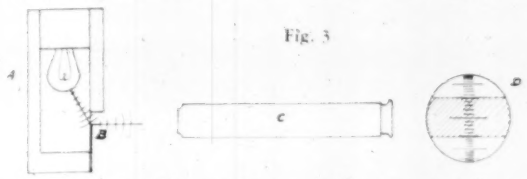


Fig. 2

n be reduced to less than 0.00025" in width. The line is owed through a 40-power microscope *C*. The cross-hatched tion of the field *D*, represents the amplitude of vibration. and *G* of Fig. 1 show this set-up as it applies to the

Fig. 3



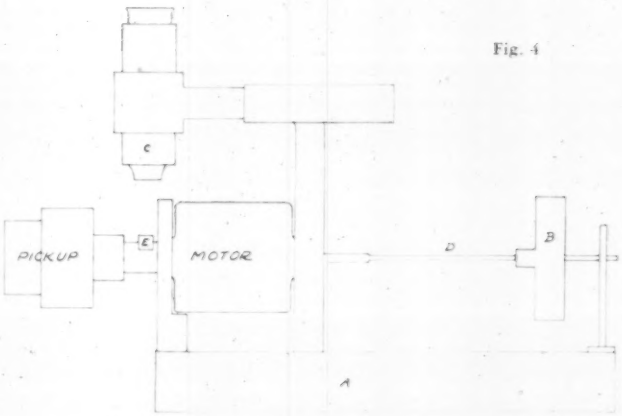
linear calibrator. The accuracy of measurement by this method is a function of the line width in relation to the total amplitude being measured.

A universal joint, driven at an angle, is a means often used for calibrating torsional vibration units. This introduces a second-order rotational vibration. Calibrations can be obtained also by introducing torsional vibration without rotation. The following discussion pertains to the latter method.

In the pick-up unit under consideration, the output electrical indication is produced by differential motion between the inertia body and the part following the torsional vibration. This relative motion may be produced without rotating the unit, and the calibration will be valid, if certain factors can be proved to have no effect on the calibration.

One of these factors, the 1-order indication, may be introduced by the effect of extraneous fields on the unit. This may be checked by rotating the unit at constant speed and observing the indication from the unit. In improperly

Fig. 4



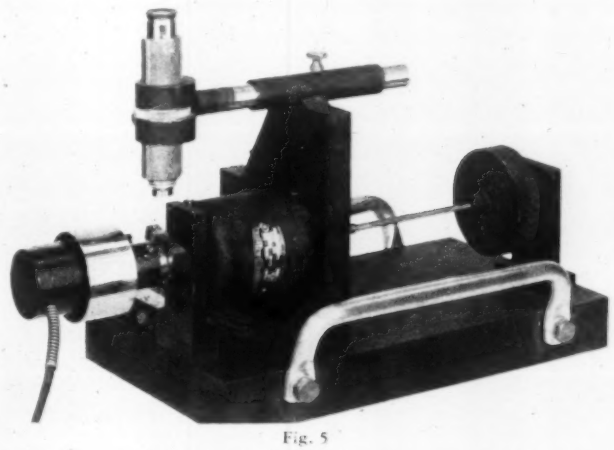


Fig. 5

shielded units, the earth's field may cause indications of significant amplitude.

The second factor is the effect of linear vibration on torsional indications. This effect is a function of unbalance in the unit. This may be checked by rotating the unit on a slightly eccentric shaft. If the unit is in balance, the linear vibration will produce only a negligible indication; but, should unbalance be present, a significant 1-order indication will be observed.

These two factors determine at least in part the limit on reliable low-amplitude readings.

The third factor is the effect of relative torsional displacement of the inertia unit due to the rotational load. This relative displacement may be checked by a strobotac, and the error due to displacement may be determined by actual calibration. This error is negligible if the displacement plus the torsional amplitudes does not exceed the limits of amplitude linearity.

After these three factors have been investigated and evaluated, the unit may be calibrated without being rotated. The torsional calibrating unit as well as the linear unit takes advantage of resonant vibration to reduce the required power and to attain higher frequencies of vibration.

Fig. 4 is a simplified drawing of a torsional vibration calibrating unit. The unit consists of a special motor capable of producing torsional vibration, the rotor of which is connected to a metal disk *B* by a thin shaft *D*. A quite rigid shaft connects the rotor to the pick-up unit. In this way, the rotor and the pick-up unit act as one member of the resonant system, and the disk acts as the other. The inertia of the disk *B* is made large compared to the rotor and pick-up unit so that most of the vibration will exist in the pick-up unit. The shaft *D* and rotor are mounted in ball bearings, and the disk *B* may be adjusted along the length of the shaft to produce various resonant frequencies. Resonant frequencies from 70 c.p.s. to 300 c.p.s. may be attained by adjusting one weight. Additional weights are added to produce lower resonant frequencies.

The amplitude is measured as in the linear calibrator except that the chord of the arc of vibration is measured. Fig. 4 shows this arrangement of the microscope *C* and light source *E*. This is sufficiently accurate over the range of amplitudes of most pick-up units.

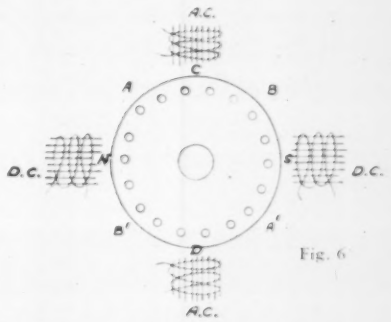


Fig. 6

Fig. 6 is a diagram of the motor used to produce torsional vibration. A ½-hp., 4-pole a-c. motor was rewound to fit specifications. Two opposite poles were wound for alternating current and for electrically matching a 4-ohm output transformer. The two other poles, carrying d-c. windings of about 2 ohms, are energized by a 6-volt storage battery. Since the rotor is of the squirrel-cage type, no brushes or commutator are required. This is important in reducing damping and in making the instrument more rugged.

When a voltage is applied to the d-c. field, north and south poles are set up as shown in Fig. 6. When an a-c. voltage is applied to the a-c. field, the following action takes place:

At the point where *C* is at a maximum north pole and *D* is at a maximum south pole, the resultant field, as seen by the rotor, is north at *A* and south at *A'*. One-fourth cycle later, the poles of the a-c. field come to zero, and the resultant field is that produced by the direct current alone. Thus, the resultant north pole has moved from point *A* to a point directly beneath the north pole of the d-c. field. One-fourth cycle later, the alternating current field has produced a north pole at *D* and a south pole at *C*. The resultant field at this instant has moved so that the north pole is at *B'*, and the south pole is at *B*. Thus, (with equal a-c. and d-c. fields) the resultant field moves through 90° and will return during the next half cycle. The induced current in the squirrel-cage rotor causes the torque in the rotor to follow the field. This produces a torsional force and consequently torsional vibration. When these torsional forces on the rotor are in tune with the resonant frequency of the torsional system, considerable torsional vibration may be produced.

Figs. 2 and 5 are photographs of the linear and torsional calibrators now in use. *(Continued on page 312)*

Two Needles Are Better Than One

By RAY C. SHRADER
Chief Pilot, Braniff Airways, Inc., Dallas, Texas

BY the time this story appears in the October issue of *Instruments* magazine, Braniff Airways will have installed on its fleet of 21-passenger liners a new navigational instrument called the Sperry dual automatic direction finder. This is a refinement of the Sperry-RCA automatic direction finder which Braniff introduced to the air transport industry in December 1939. It was conceived jointly by Reeder G. Nichols, chief radio inspector for air carriers of the Civil Aeronautics Authority, and L. H. Luckey, our operations manager. They were sitting in Luckey's Dallas office in January, 1940. Nichols had just finished an inspection of Braniff's radio navigational facilities and was congratulating Luckey on the performance which our airline was enjoying with the then-new single-needle direction finder. To demonstrate a point of discussion Luckey was using the top of a round tobacco can to simulate the compass face of the direction finder and a pencil to simulate the needle.

The author, a Kelly Field grad, is a Captain in the Army Air Corps Reserve.

"You know," said Nichols, "It would be great if someone would develop a direction finder with two needles, like clock hands, so you could automatically get a cross bearing."

"Yeah," said Luckey, subconsciously placing a second pencil in position on the tobacco can top, "it sure would."

"Wait a minute!" said Nichols. Then, after a pensive pause: "That may not be too tough. Now that the principle of coördinating a radio receiver, a radio compass and a compass face has been worked out, I don't know but what two radio receivers, two radio compasses and two needles can't be coördinated."

"Why not?" exclaimed Luckey.

"Why not!" decided Nichols, and went to work on the problem.

So, Nichols the radio wizard and Luckey the operations genius put their heads together. As Luckey modestly recalls, Nichols figured out what could be done to design and produce their brain child; and "any stiff could have figured out what could be done with the product."

Sketches and specifications were drawn up and the problem of production was presented to the Sperry aircraft radio department. Sperry decided it could be done. Braniff placed the order.

As its name implies, the dual direction finder has not one but two radio-operated needles, tuned to different radio stations. With its aid a pilot can establish a sky highway on which he can guide his ship from one city to another. Or, he can tune one needle to a radio station to the right of his course, the other needle to a radio station to his left, and thereby determine the ship's exact position.

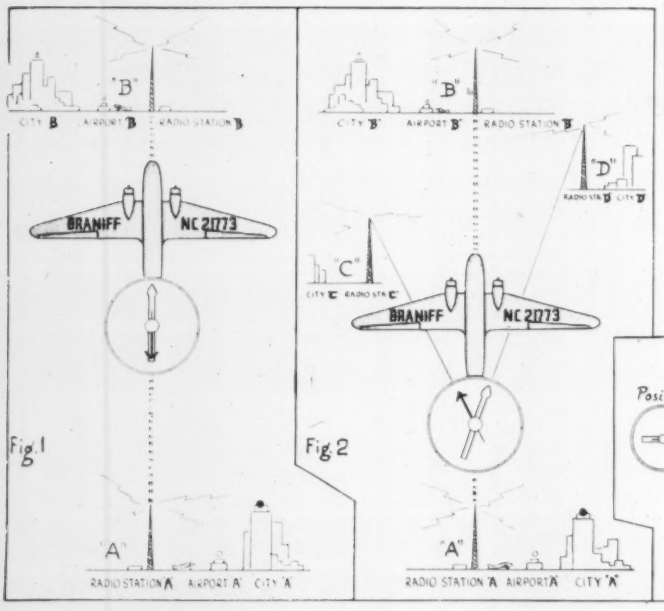
Let me illustrate by the case of a Braniff pilot who takes off from Chicago and proceeds to Kansas City. After he completes his take-off he tunes in one direction finder needle back to a Chicago radio station. The other needle he tunes in to a station in Kansas City. As long as the two needles are 180° apart, or at "six o'clock," he is proceeding on a straight course. Or, flying from Chicago to Kansas City, the pilot could tune one needle to Ottumwa, Iowa, the other to Quincy, Illinois. Where the angles of the needles' positions crossed on his airway map would indicate the plane's exact position.

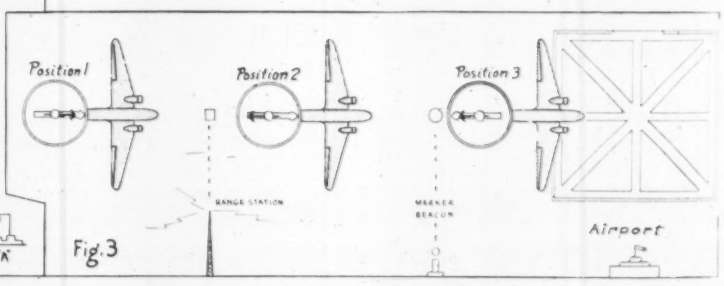
In addition to the advantages I have described, Luckey foresees other benefits to be derived from the new device.

First off, it could supplement, even replace, the present radio beam on which domestic airlines navigate from point to point. The beam is a radio track emanating from continuously transmitting radio stations located along airline routes. As they fly a course, pilots listen to the signal through earphones. The signal is so transmitted that as long as the pilot hears a continuous tone signal he is "on course." If the signal becomes a dot-dash he knows he is to the right of his course; if he hears a dash-dot he knows he is to the left.

With the aid of the dual direction finder the pilot can

(Continued on page 308)





Diagrams showing the three principal uses of the new Sperry automatic dual direction finder.

Fig. 1 shows how the instrument is used to navigate on a straightaway course between cities. Leaving city "A" the pilot tunes one pointer-needle (illustrated as the black one) to a radio station in or near city "A." The other needle (illustrated as the white one) he tunes in to a radio station in or near his destination, city "B." As long as the two needles are 180 degrees apart, the pilot knows he is flying a direct straightaway course to his destination.

Fig. 2 illustrates how the dual direction finder is used to orient a ship's position. Proceeding from city "A" to city "B" the pilot checks his position by tuning one needle to any radio station left of his course, indicated as city and radio station "C," and by tuning the other needle to any radio station to the right of his course, indicated as city and radio station "D." The apex of the corresponding angle on the pilot's route map indicates the ship's true position.

Fig. 3 illustrates how the instrument is used in instrument approaches, preparatory to landings. As the pilot flies toward the airport at which he is to land (Position 1), he lines up the needles by tuning one needle to the radio range station, and the other to the marker beacon. In this position the pilot knows he is heading straight for the runway as long as the two needles exactly overlap each other. As he passes over the range station (Position 2) the needle tuned to the range station swings completely around and continues to point back at the range station. The needle tuned to the marker beacon continues to point ahead. As long as the two needles are 180 degrees apart, the pilot knows he is proceeding on a straight line from the range station to the marker beacon and is lined up for landing on the runway just beyond the marker beacon.

As the ship passes over the marker beacon (Position 3) the white needle swings completely around and continues to point back at the marker beacon. In the meantime the black needle also continues to point back at the range station. The pilot knows that as long as the two needles overlap each other, pointing back at the marker beacon and the range station, he is flying directly from the range station to the marker beacon to the runway and that he should be in a position to land.

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LET'S GO! U.S.A. · KEEP 'EM FLYING!

The Electromagnetic Balance—A High-precision Measurement and Control Device

By FRED S. EASTMAN

Professor of Aeronautical Engineering (and Wind Tunnel Supervisor), University of Washington, Seattle, Wash.

IT was desired about ten years ago, at the University of Washington, to measure and record unsteady air loads imposed on airplane models in a wind tunnel. For that purpose the Electromagnetic Balance was developed[1] by the writer. It was observed that the device was suitable for a wide variety of measurements, but until recently no effort has been made to apply it to other than a few special problems involving the measuring and recording of forces. The balance consists of a coil of wire suspended in the air gap of a magnet in much the same manner as the coil of a dynamic loud speaker. The suspension is designed to allow the coil to move normal to the magnetic flux with a minimum of restraint. The current supplied to the coil is controlled automatically so that the travel of the coil under full load is only a few thousandths of an inch. The result is that any force applied to the coil is instantly balanced by a corresponding increase in current. An extremely accurate proportionality between the current and the applied force is insured, by supplying the flux with permanent magnets and controlling the current with photocells. Evidence now available shows this proportionality to be well within 0.1% on balances now in use. In obtaining this figure it was necessary to include the influence of auxiliary equipment and therefore the accuracy of the basic unit may be many times greater than indicated.

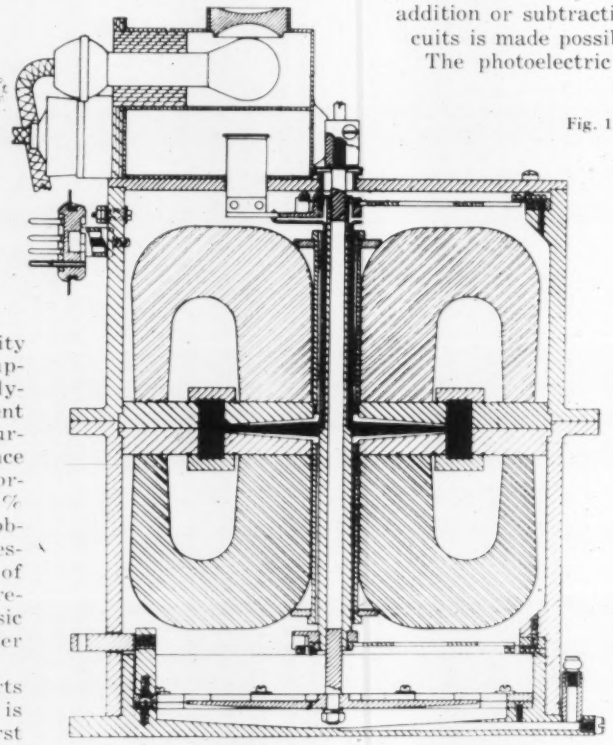


Fig. 1

The arrangement of parts may be seen in Fig. 1, which is an assembly drawing of the first permanent magnet unit. The cross-section of the ring-shaped coil appears as two black rectangles. The coil is attached to a central disk which in turn is attached to a tube extending up through the center of the permanent magnets. The mirror which controls the light falling on the photocells is attached to the top of the tube, and an adjustable dash pot is attached to the bottom of the tube. The load to be measured is applied axially to the top of the tube and can be exerted either up or down. The coil and connected parts are free to move up and down about $\frac{1}{32}$" from their neutral position. The permanent magnets are of Alnico which can be cast in the desired form. The maximum normal operating pull obtained from this unit is six pounds, but larger loads can be balanced for short periods of time. The housing stands 10" high and 9" in diameter, and the unit weighs near 100 lbs. complete.

Usually two or more windings are provided in the coil. Current passed through coil *A* will produce a force which will be balanced automatically by the controlled current in coil *B*. If the weight of the coil is balanced out mechanically, the current in coil *B* will be proportional to the current in coil *A* and the multiplying factor is determined by the number of turns in the coils. Accurate adjustment is accomplished with shunts connected across the coils, and any series of multiplying factors can be provided with a selector switch and appropriate shunts. In this way it is possible to multiply a current in microamperes by 1000, giving accurate readings on a milliampere recorder. With three windings on the coil, the current from two separate circuits can be passed through coils *A* and *B* respectively, and the automatically-controlled current in coil *C* will then be a measure of the sum of the pulls of coils *A* and *B*. Thus, the addition or subtraction of any number of separate circuits is made possible.

The photoelectric control circuit now in use operates on 110 volts a.c. and will easily deliver 7 watts of controlled d-c. output. The normal maximum current is 0.15 amp. but this can be increased considerably if the demand is intermittent. There is no apparent obstacle to providing considerably greater output if the additional expense is warranted, but the present equipment is ample to operate numerous recording instruments in series and at remote points, or to operate small solenoids controlling higher energy circuits.

The frequency to which the coil will respond depends upon the resistance in the output circuit, the ampere-turns in the coil and the sensitivity of the photoelectric unit. Extremely accurate reproductions of harmonic load variations have been obtained up to one cycle per second, which was the limiting frequency for the recording equipment employed. Good response may be expected up to 25 c.p.s. under favorable conditions. Doubtless, higher frequencies can be recorded if consideration is given to the requirements.

Variations in line voltage cannot affect the current output because this is automatically adjusted to keep the coil in position. However, sudden fluctuations in voltage cause unsteadiness in the output current which is sometimes observable when the coil is shunted for high sensitivity. This trouble can be minimized if not eliminated by adding special filtering and voltage-regulating equipment to the vacuum-tube circuit. Nevertheless, the best solution to this problem is to provide a steady voltage supply.

THE LATEST BALANCE

During the past year the Instrument Laboratory Incorporated (Seattle, Wash.) has manufactured a number of electromagnetic balance units. Numerous improvements have been built into them as a result of collaboration between the instrument company, the Lockheed Aircraft Company, and the writer. Fig. 2 shows the balance complete with photoelectric control circuit, indicating instrument and shunts

[1] Fred S. Eastman. An Electromagnetic Balance for Force Measurement or Current Control. University of Washington Engineering Experiment Station Bulletin No. 60, 1932.

[2] See also: P. A. Borden. Applications of the Electric Balance. *Instruments*, Vol. 2, 1929, pages 425-432.—MFB

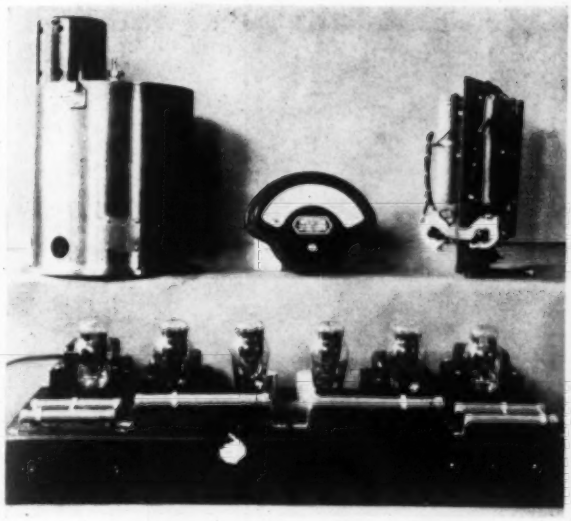


Fig. 2

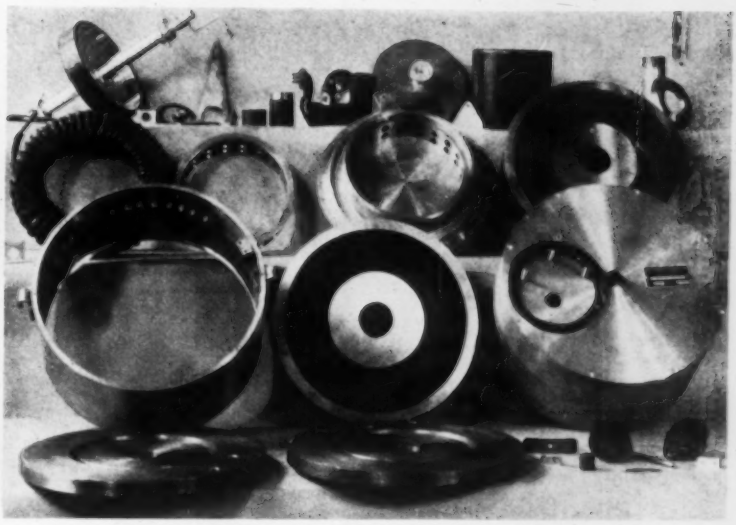


Fig. 3

providing eight different ranges. The maximum range covers 10-0-10 lbs. and the minimum range covers 0.05-0-0.05 lbs., but all are easily adjusted to cover somewhat greater or less load. A Weston Model 271 instrument was chosen in preference to a more accurate laboratory type, because readings were to be taken by photographing an instrument panel providing all pertinent data. Fig. 3 shows the various parts of the balance. The coil (upper left corner) is shown attached to the central tube, and the little mirror controlling the light striking the photocells may be seen projecting out from one end of the tube. The heavy coil, just below, is used to magnetize the permanent magnets after assembly, and is left in place although it serves no useful purpose unless it should be desired to alter the magnetization later. The two castings to the right of this coil are parts of the adjustable dash pot, and the casting on the far right on the same row is one of the Alnico permanent magnets. Another magnet appears with the housing in the row below and the pole-pieces are lying flat at the bottom.

LOAD MEASUREMENTS

Six of these balances are used for measuring the air loads on airplane models in the large wind tunnel at the University of Washington, and an additional balance of this type is used to measure air speed.[2] Fig. 4 shows the installation of one of those used to measure the forces on the model. Loads up to 3000 lbs. on the model are reduced by mechanical linkage to approx. 10 lbs. applied to the balance coil. The notched beam with its adjustable weight is used to balance out the major part of the load when it is desired to measure small increments. By so doing, a change of a fraction of a pound in 1000 can be measured with ease. The entire weighing system is remarkably free from hysteresis and lost motion, because flexure pivots (thin metal strips) have been used throughout.[3,4] The effect of the stiffness of these pivots can be detected only on the most sensitive ranges, and being linear, it can be included in the calibration. Pivot stiffness would be objectionable were it not for the extremely small movement of the balance coil even under full load.

AIR SPEED MEASUREMENTS

Air speed in the wind tunnel is measured as in the case of a Venturi tube, by measuring the pressure difference between the low speed portion and the high speed portion of the air channel. Fig. 5 shows a pressure balance recently constructed for this and other laboratory purposes. The

(Continued on page 310)

[2]Frederick K. Kirsten and Fred S. Eastman. The University of Washington's New 250-MPH 8 × 12 Foot Wind Tunnel. *Journal of the Aeronautical Sciences*, Vol. 6, No. 12, Oct. 1939.

[3]C. H. Gibbons. Materials Testing Machines. *Instruments*, Vol. 8, No. 3, March 1935, pages 76-78.

[4]Fred S. Eastman. The Design of Flexure Pivots. *Journal of the Aeronautical Sciences*, Vol. 5, No. 1, Nov. 1937, pages 16 ; 21. (Also a more detailed analysis by the same author is presented in University of Washington Engineering Experiment Station Bulletin No. 86, 1935.)

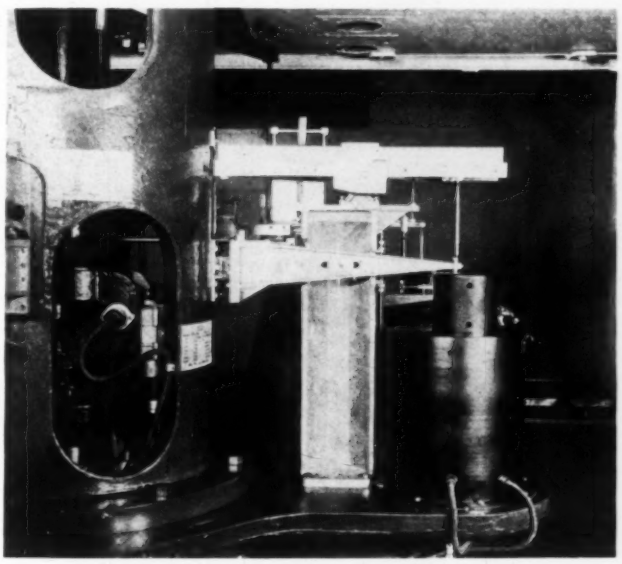


Fig. 4

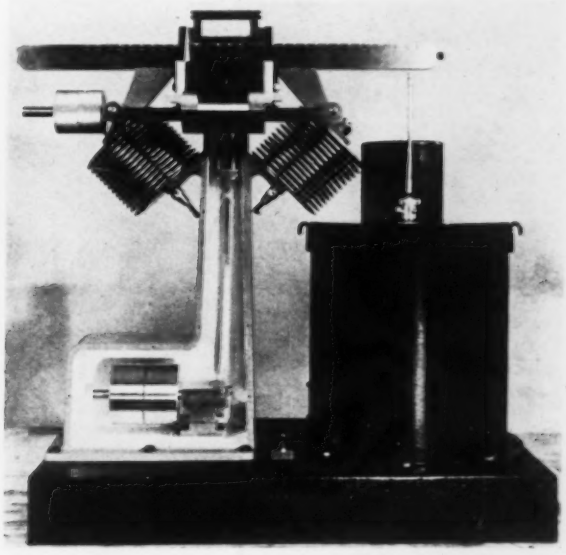


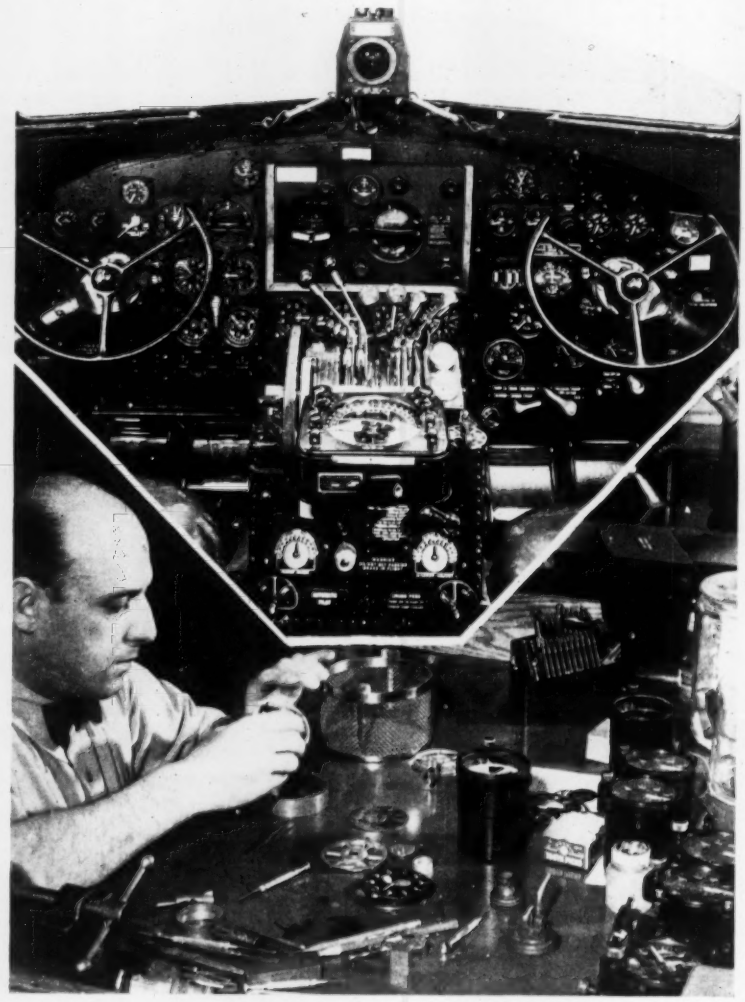
Fig. 5

An Outline of AA's Maintenance Procedure

By R. W. MAJOR

General Foreman, Instrument Shop, American Airlines, New York.

MAINTENANCE inspection and repair of the vital engine and flight-control instruments which make up the instrument panel of a DC-3 fall to the American Airlines Instrument Overhaul Shop at the Flagship fleet's base at LaGuardia Field, New York City. Our department (which has been credited with its share of responsibility for the high operating efficiency of the airline) employes forty-eight men, each an expert in some phase of instrument work, in an air-conditioned, scientifically-lighted work-shop in Hangar No. 5. Each of the flight instruments under our jurisdiction is removed from a DC-3 or DST at the end of 700 hours of aircraft flight time. It is disassembled, inspected, cleaned, and adjusted. It is not replaced in the aircraft until after it has been subjected to test stand checks for complete accuracy. After a total of 2100 hours has been logged on an instrument, it is scheduled for a major overhaul. Taken from service, the instrument is completely disassembled and every part is examined. Any worn mechanism which cannot be repaired is replaced. After rebuilding the instrument, we check it on the test stand against a "master." Then it is again ready for service.



Among the instruments overhauled are: Directional gyro unit, artificial horizon, rate-of-climb indicator, altimeter, clock, air relay, manifold pressure gage, compass, bank-and-turn indicator, airspeed indicator, tachometer, cylinder-head temperature indicator, air temperature indicator, and a number of others. A log book is kept of all flight instruments to provide accurate time checks. We also keep records of repairs on all instruments in the eighty Douglas Flagships and in the five Stinson Reliants used for survey and instrument flying instruction.

Single Unit for Numerous Aircraft Radio Tests

By RALPH CORE

Foreman, Radio Shop, American Airlines, New York.

COMBINING a group of radio test units which formerly were strung out over the bench, the staff in the American Airlines radio shop designed a new test unit for the overhaul shop at LaGuardia Field.

The new unit we developed will test all receivers used in the Flagship Fleet. In reality, it is a DC-3 or DST radio system condensed into a carrying case. It not only tests receivers as if they were actually working in the ship but sends tones through different parts of the circuits connected with the receiver to test vital parts within the receiver. It supplies its own power, as well as that for the receiver on test, from the regular 115-volt house current. Its design permits tests on new receivers and additional units in the future. We made it easy to operate. All controls are marked and by turning them "on" the set begins to function. We guarded against mistakes in connecting a set to a unit in that the cables employ Jones plugs: this system acts like a Yale key and prevents damage to sets or testers.

The large name plate in the center is the control for the 29A receiver, one of the latest types, and the Collins transmitter, which although it operates on ten different frequencies and has an automatic electric shift, is so designed that every operation can be made through this unit quickly and efficiently. These units are available to mechanics who overhaul all receiving equipment in our shop, and are used by inspectors in the final check and alignment of the receivers.

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Production is smoother and faster with Kester Cored Solders because the self-contained flux makes them easier to use—flux and alloy are in controlled balance, both as to kind and amount. Guesswork is eliminated.

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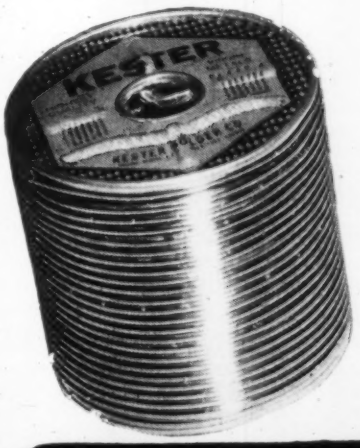

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Notes on Some Engine Instrument Tests

By MOREY EGGLESTON

Foreman of Instrument Shop, Western Air Lines Corp., Burbank, Calif.

IN spite of the shortage in planes and equipment caused by the National Emergency, Western Air Lines is maintaining a high percentage of completed and uninterrupted flights. An important factor in maintaining this record is the proper overhaul and maintenance of the instruments.

Perfect operation of instruments during flight requires exactness in their overhaul and stringent tests before they go into an airplane. The instrument shop, in which this work is done, presents an interesting study of technical achievement. In such a shop it is necessary to reproduce almost every condition to which the instruments are subjected in flight through all atmospheric changes and engine conditions. In order to do this so thoroughly that a pilot can always rely absolutely on the accuracy of the information provided by his instruments, a separate test must be devised for every instrument used in aircraft power plants.

The testing equipment may be divided into two groups: (1) means for duplicating the operation of the instrument; (2) standards for accurate checks of the calibrations.

Herewith are illustrations of apparatus and brief explanations of the procedures used by Western Air Lines in testing engine instruments such as manifold pressure gages, tachometers and temperature indicators.

The manifold pressure gage tells the pilot the pressure of the gaseous mixture entering the cylinders. To gain full efficiency from the engine, the pilot keeps the pressure at the value prescribed by the engine manufacturers (in Western Air Lines' case, Pratt & Whitney). These gages have a range of 10 to 50 inches of mercury absolute. Figs. 1 and 2 show the manifold gage test stand developed in this shop. For testing purposes it is necessary to increase and decrease the pressure from that of normal atmosphere and apply this change simultaneously to the instrument and to a mercury manometer. A surge tank is used to replace the engine and to eliminate pulsation. A mercury column with an adjustable scale calibrated from 10 to 50 inches is used as a standard measure to check the instrument.

Going hand-in-hand with the manifold pressure gage in contributing to safe and efficient operation of the airplane engine is the engine-speed tachometer. This is a remote-reading system composed of two parts: a magneto and an indicator. The magneto is a two-pole d-c. generator with output directly proportional to engine speed. It develops 6 volts per 1000 r.p.m. of its own shaft. The indicator has a full-scale deflection of 270°. Its mechanism operates as does the conventional d-c. movement but magnetic flux is distributed over this large deflection by suitable design of coil, magnet and pole-pieces.

In our shop, magnetos are checked by a true null method, the magneto voltage at an exactly-known speed bucking an exactly-known opposite voltage. A Strobotac, a standard voltmeter (accurate to 0.5%) and a balance indicator rated one volt (1000 ohms-per-volt) are used. A variable-speed motor drives a shaft to which are attached the magneto and a stroboscopic disk

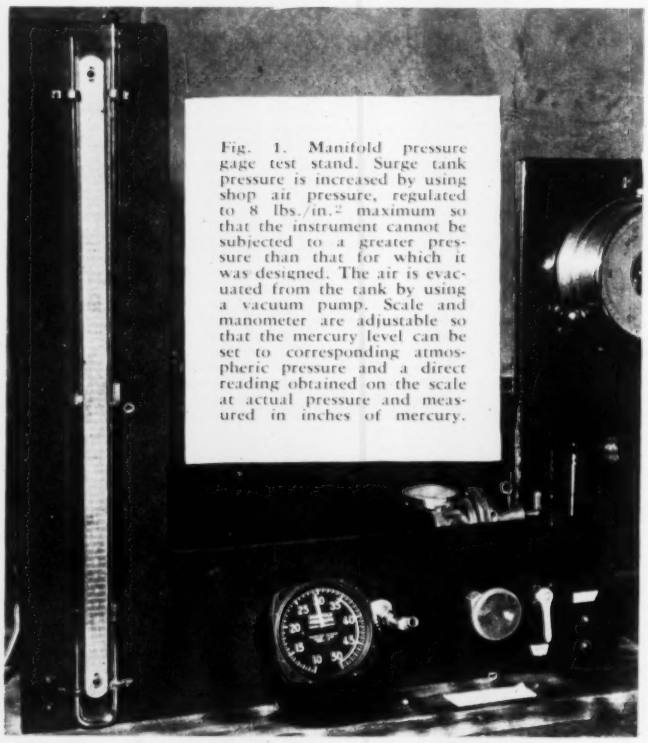

Fig. 1. Manifold pressure gage test stand. Surge tank pressure is increased by using shop air pressure, regulated to 8 lbs./in.² maximum so that the instrument cannot be subjected to a greater pressure than that for which it was designed. The air is evacuated from the tank by using a vacuum pump. Scale and manometer are adjustable so that the mercury level can be set to corresponding atmospheric pressure and a direct reading obtained on the scale at actual pressure and measured in inches of mercury.

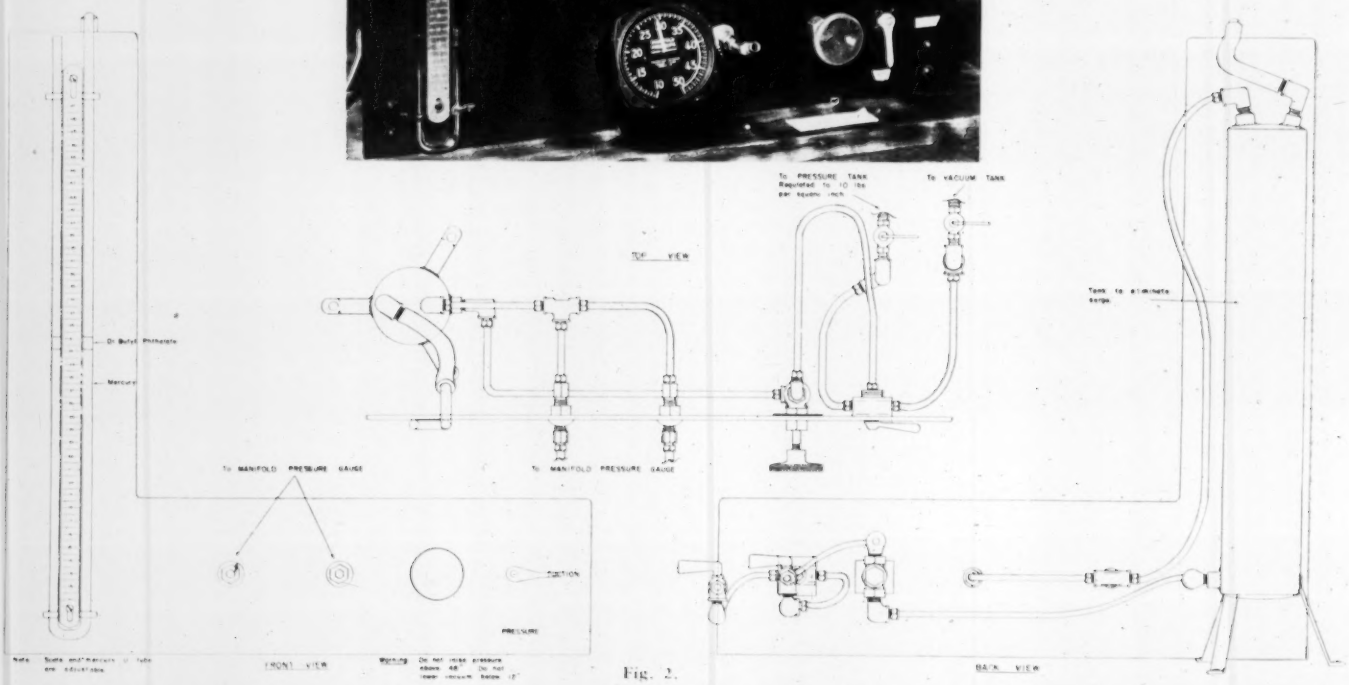

Fig. 2.

upon which are focused the flashes from the Strobatac. The magneto is tested by driving it at 1800 r.p.m. (determined by the Strobatac) applying 10.8 volts to the standard voltmeter, and adjusting the magnetic shunt until the balance indicator shows no deflection. See Fig. 3.

The engine speed indicating instrument is tested as may be seen in Fig. 4, by connecting it in multiple with a standard voltmeter to a variable d-c. voltage source. A voltage-to-r.p.m. reference chart is used for the particular type of indicator being tested.

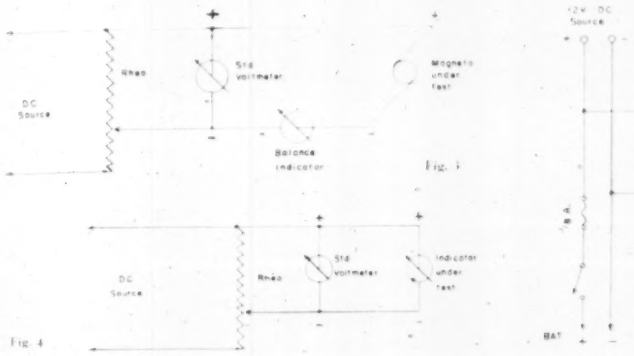

Fig. 3

Fig. 4

The pilot is able to control the temperature of the air at the carburetor scoop, and that of the oil in the engine, by using engine equipment designed to regulate heat and cold. The various temperatures at these points are measured by electrical-resistance thermometers—which we in the field of aviation call electrical type temperature gages. We prefer them to the capillary type remote-reading thermometers because they are easier to install and less subject to damage.

There are two parts to the gage: the indicator located on the instrument panel and the resistance bulb attached to the engine at the point of temperature measurement. The instrument operates on the Wheatstone bridge principle. Part of the bridge circuit is contained in the indicator and the remaining arm is formed by the resistance bulb. The bulb resistance varies with temperature. Each change causes the Wheatstone bridge to be unbalanced in a direction and magnitude corresponding to the temperature to which the bulb is exposed. The galvanometer of the conventional balanced Wheatstone bridge circuit is replaced by the indicator, which is calibrated in degrees Fahrenheit.

The indicator is tested by replacing its bulb with a rheostatic switch made up of resistors calibrated to represent the resistance of the bulb at various temperatures. This makes it convenient to check the indicator at various resistance values. See Fig. 5. A table is supplied by the manufacturer for converting temperature to resistance values.

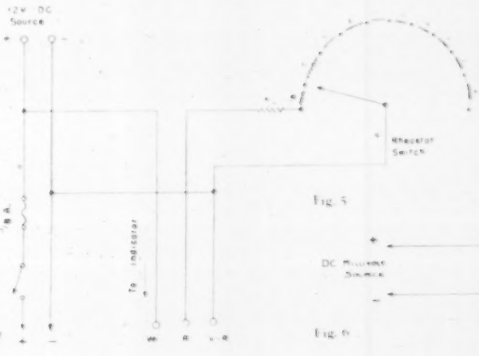

Fig. 5

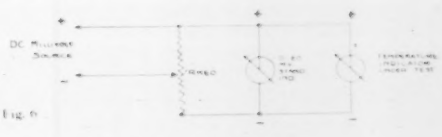

Fig. 6

In the operation of aircraft engines it is necessary to know at all times the temperatures of the cylinder heads or bases. Not only is there a temperature limit beyond which it is not safe to operate, but the pilot uses these temperature indications, in conjunction with other readings, to obtain efficient performance from his engines. A thermocouple is attached to each point at which the temperature is measured. A pair of leads (whose resistance is calibrated to two ohms) connects the thermocouple with the cockpit indicator which is a millivoltmeter calibrated to read from 0 to 600°F.

The test for this instrument is similar to that of the engine-speed indicator, except that in this case a 0-to-20 millivoltmeter (1% accuracy) is used for a standard. See Fig. 6. The readings on the millivoltmeter can be compared with the manufacturers' temperature-emf. conversion chart.

Fig. 7. Test and Calibration Equipment for Sperry Gyro Instruments, Western Air Lines Instrument Shop

ANNOUNCING ANOTHER AVIATION ISSUE

MORE aviation-instrument articles are coming in as this issue—already enlarged and delayed—must be put on the press so as to reach you before October has entirely gone by. And others are promised! There is only one thing to do . . . and you may be certain that it will be done . . . soon!

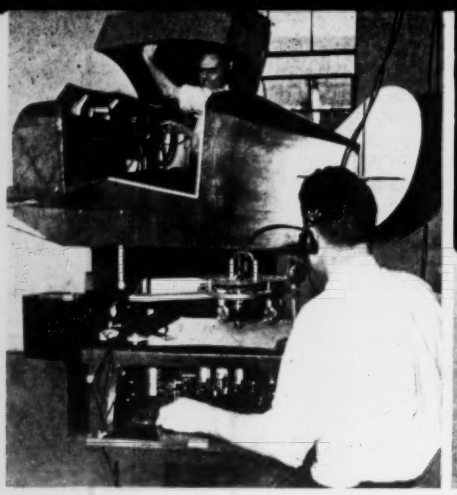

Fig. 1. The Link trainer simulates the characteristics of a plane in flight. Its instrument panel contains all the instruments necessary for instrument flying; and all navigation situations of actual flight can be duplicated.

Fig. 2. Having received twenty-odd hours of Link trainer practice, the students now take up actual instrument flight. Chief Instrument Instructor Davis (right) gives a student captain (in the *enclosed* rear seat) instructions as to the course he is to fly. They are in one of TWA's three Stinson trainers, which are equipped with all the essential navigation and radio instruments found on the line's Douglases and Stratoliners.

Fig. 3. The control room of a TWA four-engine Stratoliner presents an impressive array of instruments. All the principal navigation instruments are in duplicate. There are over 250 dials, switches, etc. in the cockpit.

Instrument Flight Training for TWA First Officers and Captains

By HUGH DAVIS

Chief Instrument Flight Instructor, Transcontinental & Western Air, Inc., Kansas City, Mo.

IT was in the spring of 1936 that I had my first experience with instrument flying. It was almost a fatal one. I couldn't fly on instruments and had never thought it particularly important until one morning when I foolishly took off from the Savannah, Georgia, airport for Jacksonville, Florida, with a ceiling of only 500 feet. It was expected to clear but it didn't. I flirted with tree-tops and hills, groping through fog over a good part of Florida before I was lucky enough to slip into Jacksonville. I determined then and there that I wouldn't get caught in weather like that again without knowing how to fly on instruments.

Instruments are the life-blood of both the world's oldest and youngest methods of transportation. To the mariner and to the airman, knowledge of instrument procedures is a vital necessity. This applies particularly to scheduled flying which, were it not for modern radio and navigational instruments, would be an impossibility.

The instrument flight training division of TWA is designed to equip pilots with every known method of instrument navigation that contributes to the safety and dependability of flight. For training purposes, the staff utilizes four Link trainers and a fleet of single-engine Stinsons.

Owing to the rapid expansion in TWA operations in the past two years, we have had a student first officer class in session practically 100 percent of the time. In addition to these classes, which last six weeks, our department has conducted the advanced Link and Stinson instruction for first officers being checked out as captains. Although I will not go into the details here, our training course for student first officers and student captains involves much more than just the actual schooling in instrument navigation procedures. They undergo intensive instruction in meteorology, equipment familiarization, radio, civil air regulations, and company regulations—all taught by experts in each field.

TWA's requirements for pilots are strict. Among other qualifications he must have a valid government instrument rating. However, the possession of such a rating does not, by any means, qualify him in the eyes of the company to pilot one of our transports. He has the basic knowledge but not the specific knowledge required for long-range instrument flying.

There are various types of procedures and approaches used by a pilot in orienting himself depending on the range pattern* of the airport in question. The student first officer, in many cases, has experience with just one type of range station—the type on which he trained for his instrument rating. Nor is he familiar with the additional instruments to be found in the control cabin of a transport plane. To give him all this added knowledge is the function of the Instrument Instruction Division.

The student first officer is already an accomplished flyer and merely needs experience with the new instruments and procedures he will use. Five hours of instruction in the Link trainer gives him the necessary familiarization. After he has completed the other work required, he is checked out as a first officer and assigned to duty.

In the past, the first officer did not again receive extensive instrument navigation training other than that conducted through company correspondence and lectures until he was ready to be checked out as captain. Under a new plan now in effect, TWA first officers are given in order of seniority the same instrument navigation training formerly taught when they were being checked out to captain status. The new policy means that as far as instrument flying is concerned the first officer will have the same technical knowledge as the captain and will lack only the actual flying experience required before check-out to captain status is allowed.

As company expansion demands new captains, those qualified by experience to take the captain check-out will only need to go through the line checks, transition flying, and ground course required in the Captains' School, since the student captains already will have their advanced instrument training. This advanced instruction in instrument flight procedures and techniques requires approximately 22 hours in a Link trainer and from 15 to 18 in a Stinson.

A Link trainer is an intricate device that simulates the characteristics of a plane in flight. The cockpit is equipped with all essential instruments needed for navigational training, and with the machine it is possible to duplicate any number of situations and problems that will be met in actual line flying. Completely enclosed under the hood of the trainer, the student is as much on his own as if he were flying a four-engine Stratoliner on top of an overcast. His sole aids are the instruments on his panel board, consisting of Sperry artificial horizon, bank and turn, climb indicator, altimeter, directional gyroscope, compass, air-speed indicator, clock, and normal engine instruments.

In the machine he practices the three main types of orientation procedure for radio range flying. An instrument procedure that would work perfectly on one range pattern

(Continued on page 313)

*Explained later in article.

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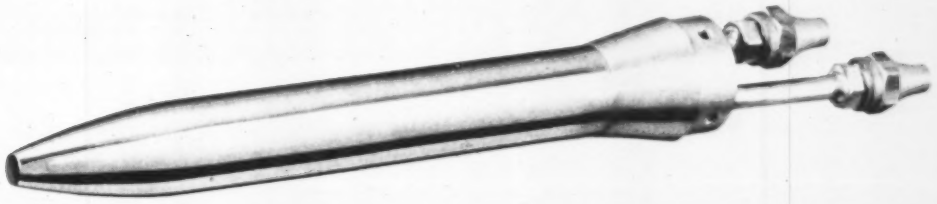

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Hydraulic-system Test Instrumentation

W. T. RATH

General Foreman, Rapairable Parts Dept., American Airlines, Inc., New York.

IMPROVEMENTS in test stands for airplane hydraulic systems were effected recently as a result of experiments which we conducted in the manufacturing department of American Airlines, Inc. Designs of the two model stands now in use in the company hangars at LaGuardia Field, New York City, have been requested by military and airline officials, indicating that this important development for aviation safety soon will receive wide use.

Hydraulic stands in common use today throughout the country employ only a hand pump to obtain the desired pressure to test only the individual part of the hydraulic system when removed from the plane.

The new, improved stands which we developed at American are outstanding in that the one which tests the complete hydraulic system has a simulated engine speed of 150 r.p.m. to 3,750 r.p.m.—or from idling speed to full throttle, using the same pump that is installed on the Flagship engine.

The hydraulic system consists of the following units: A 1,000 lbs./in.^{2} pump installed in each engine, a supply tank, landing gear retract struts, flap control strut, auto pilot control unit, a pressure accumulator, and the control panel which carries the three four-way valves to control the landing gear flaps and auto pilot, the main control regulator, relief valves piping.

At regular periods, we remove these parts from the Flagship and send them to the shop for overhaul. Each part is completely disassembled, inspected, and overhauled. Then it is installed on the test stand shown in Fig. 1 for pressure test.

We have equipped this stand with a five-horsepower motor that drives a special high-pressure pump which automatically cuts in at 1,600 lbs./in.^{2} and out at 2,100 lbs./in.^{2} The back side of this stand is identical to the front which is pictured, so that two men may test parts at the same time.

First, we see that the four-way valves are lapped in with fine compound until they will stand a 1,000-lb. test with no leak. Such a valve is being tested in Fig. 1. (Note at the right the hand pump which formerly was used.)

Fig. 1

This stand also has its own oil reclaimer to insure that the oil being used is the same as in the Flagships. All the oil from parts being tested is returned to a 20-gal. tank, and then by use of the valves shown in the photograph, we pump the oil through a special reclaimer unit and back to the main supply again.

We have found that this process picks up any articles which may have gotten into the oil while testing. It may be repeated indefinitely.

At this stand, we test the individual valves, struts, lines, brake control cylinders and all other parts of the hydraulic system at the various pressures under which they operate

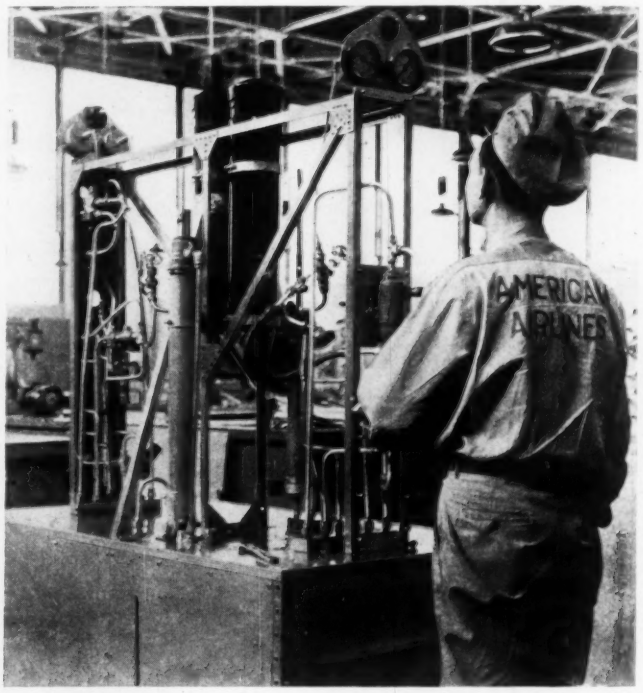

Fig. 2

on the ship. A selector valve quickly selects the pressure desired for the individual part. This, we found, is essential because brakes operate up to 600-lb. pressure, the regulator at from 600 to 800, struts at 2,000 and so forth.

After all parts have been overhauled and tested, we assemble and install them on the stand shown in Fig. 2 for run-in and final operating testing.

Since on this stand the regulator controls the pressure between 600 and 800 lbs./in.^{2}, in testing the complete system the pump builds up pressure in the accumulator until 800-lb. pressure is reached, when the regulator cuts out and bypasses the oil back to the supply tank.

By operating either a landing gear retract strut or a flap control strut, the pressure will drop to 600 lbs./in.^{2}, at which point the regulator cuts and again builds up pressure.

We follow this process in order to check all parts and to insure their proyer operation before re-installation in the Flagships.

These stands were developed by American Airlines, Inc. in its manufacturing department, of which the writer is general foreman. Stand No. 1 cost approximately $2.500 to develop, and the one for testing the complete hydraulic system, stand No. 2, about $1.200. The writer believes, however, that copies can be made at much less expense. Thev are a great improvement over the hand-pump-operated pressure system that we used before.

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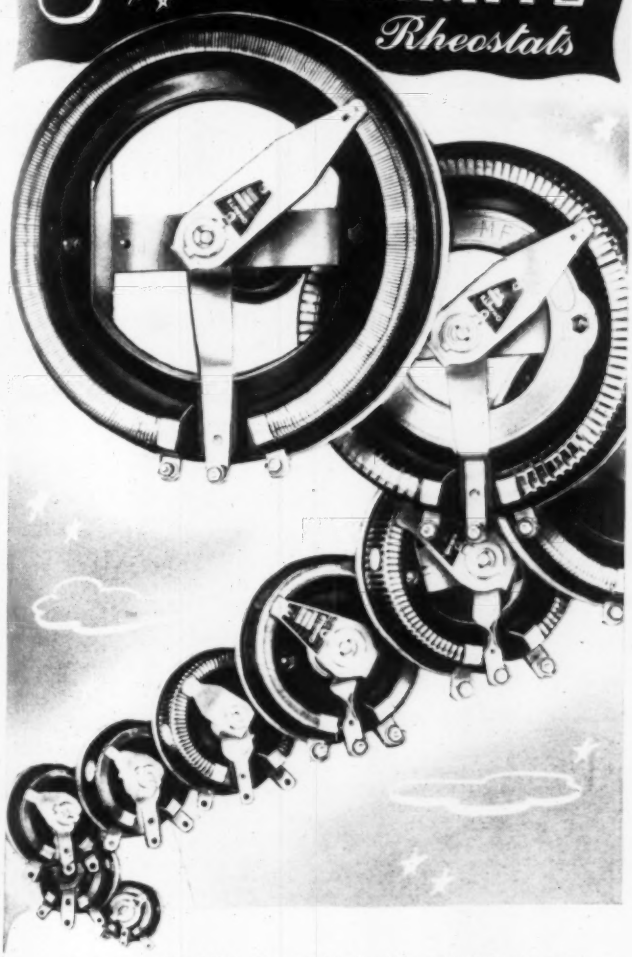

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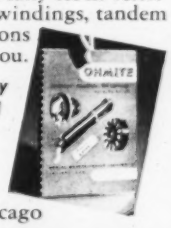

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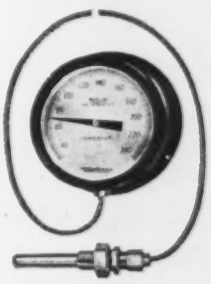

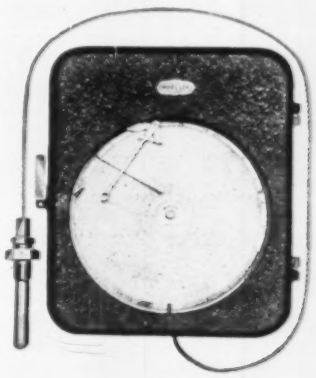

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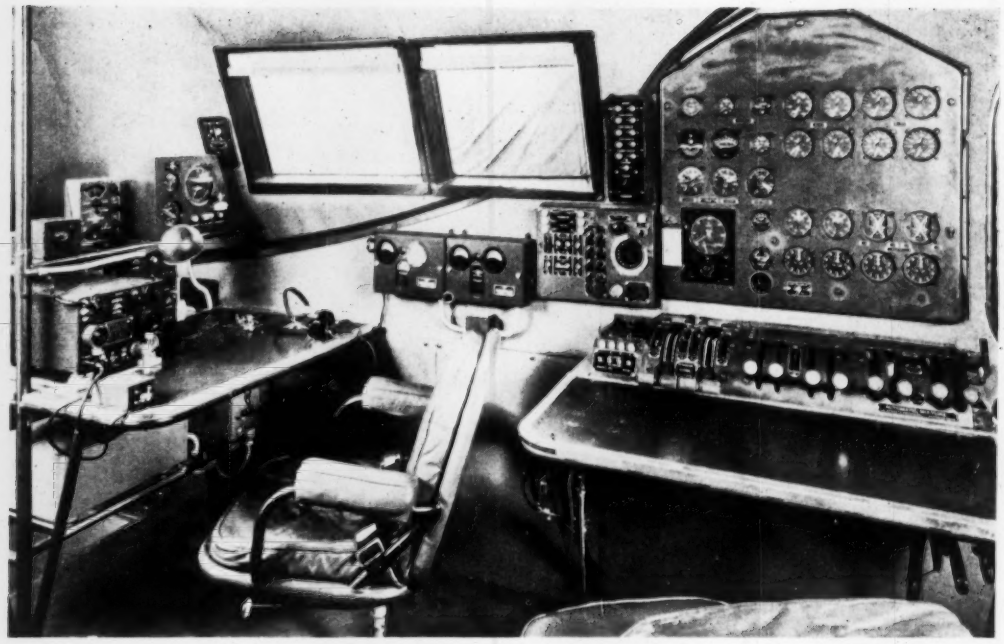

Fig. 1. Engineer's Station (right) and Radio Station (left) on the Boeing A-314 Clipper, showing some of the instruments other than those in front of the pilot.

Anti-vibration Mounting of Airplane Instruments

By S. J. ZAND and L. N. SWISHER
Sperry Gyroscope Co., Brooklyn, N. Y.

As modern aircraft instruments are required to be extremely sensitive, light in weight and comparatively small in size, it is only natural that they are operated by small forces and consequently must be delicate pieces of apparatus. Sensitivity and performance cannot be sacrificed

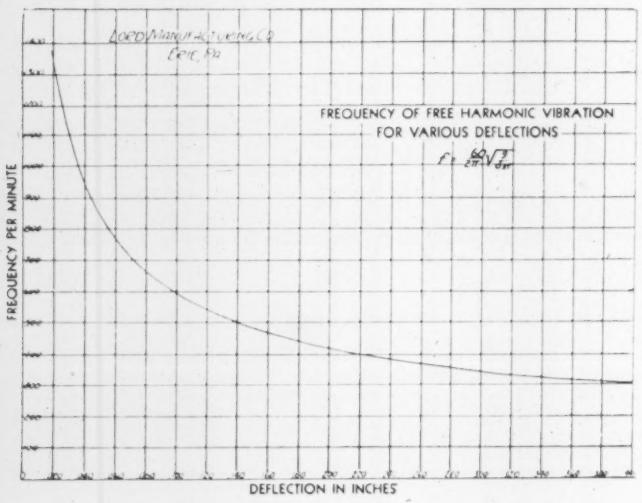

Fig. 2. Natural Frequency Curve.

for ruggedness. Furthermore, it has been demonstrated that the most delicate instruments, when properly mounted, will generally outlive the airplane.

If certain rules are followed, the insulation of an instrument board against vibratory disturbances is easily carried out and, as reported by the superintendent of maintenance and repair of a large air line, the saving will be at least 50 to 75% of the cost of maintenance of all instruments. It must be emphasized, however, that unless these simple rules are followed and the insulation of panels is carried out in accordance with scientific principles, the results may be worse than if the panel were left alone. Briefly:

(1) The panel itself must be sufficiently rigid and stiff to prevent flexual vibration. The larger the panel and the greater the distance between supporting points, the heavier the gage of the instrument board that should be chosen.

(2) The instruments should be arranged as symmetrically as possible in respect to weight distribution so as not to make the panel top or bottom heavy or one-sided.

(3) All connections to the instruments should terminate in flexible couplings, such as rubber or flexible metal hose.

(4) If shock absorbers are used to make the panel vibration-proof, they should be mounted in a plane parallel to the instrument board and passing through the center of gravity of the instrument board, because any part of a motion which necessitates the motion of the center of gravity of the support is quickly damped out.

(5) The panel with its instruments should be suspended through flexible means in such a way that the natural frequency of the assembly is not over 650 cycles per minute.

Items 1 to 4 are obvious and do not need further explanation. Item 5, however, needs clarification and this can only be done by referring to a mathematical relation between deflection and natural frequency and between natural and forced frequency.

The natural frequency of a shock absorbed assembly is approximately

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{d}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For quick reference this relation has been plotted in Fig. 2 where

f denotes the natural frequency in cycles per second
g is acceleration due to gravity 32.2 feet per second
d denotes deflections in feet

Solving for d,

$$d = g/(f^2 \times 4\pi^2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The transmissibility factor, which is the ratio between the forced or original amplitude and the amplitude obtained after shock proofing, or the measure of the disturbing force acting on the mounted instrument, is given approximately by the following formula:

$$\text{Transmissibility} = 1/[(F/f) - 1] \quad . \quad . \quad . \quad (3)$$

where F is the disturbing frequency (in our case engine r.p.m.) and f the natural (sometimes called "free"), frequency of the panel.

With these simple formulae and observing the other rules,

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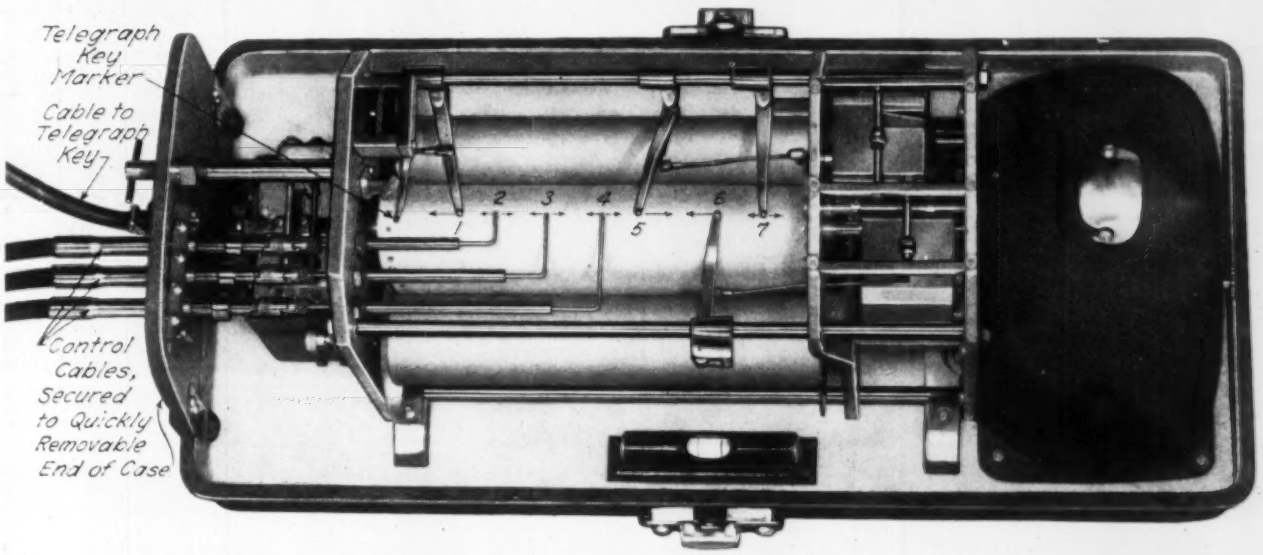

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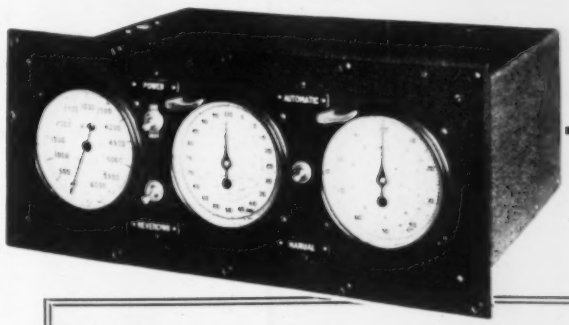

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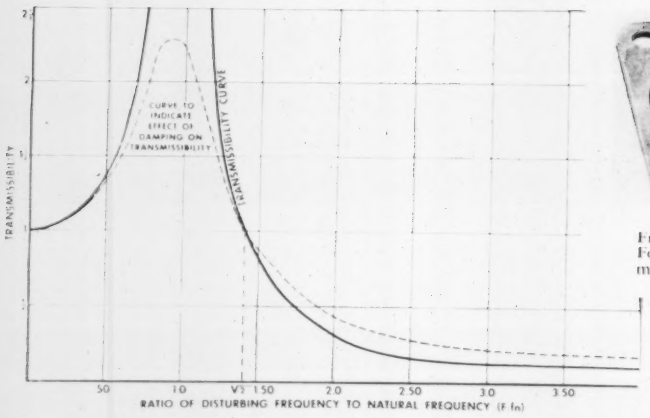

Fig. 3. Transmissibility Curve.

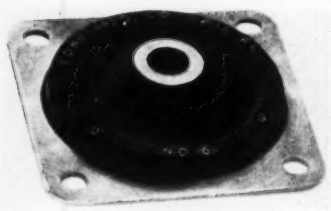

Fig. 4. Lord Bonded Rubber Plate Form Mounting used for flexibly mounting instrument panels.

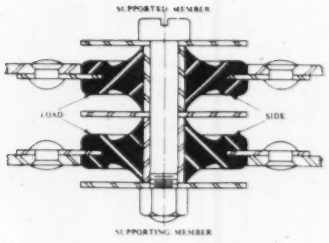

Fig. 5. Series arrangement of shear type plate form mounting. This doubles the axial softness over the rating of the individual units and gives greater capacity without loss of extreme sensitiveness.

any panel can be made vibration-proof as required for the satisfactory performance of all instruments.

Example—An instrument board weighing 30 lbs. has an amplitude of 0.024″; the engine cruises at 1800 r.p.m. Find how much the original amplitude will be decreased if the natural frequency of the panel be made 450 cycles per minute. How much must the panel deflect to obtain this natural frequency?

Solution—As in our example $F = 1800$ and $f = 450$, hence by Equation (3), (F/f) = Transmissibility = 1/15. Therefore the amplitude at the shock absorbed panel will be 0.024/15 = 0.0016″ or far within specifications.

The deflection necessary to obtain this result would be

$$\text{inches} = \frac{g \times 12}{f^2\,(\text{seconds}) \times 4\pi^2} = \frac{32.2 \times 12}{(450/60)^2 \times 4 \times 9.8}$$

= 0.175″ or approximately 11/64″.

Assuming further that there is room for only four shock absorbers, each has to have such a characteristic of deflection as to elongate 11/64″ for a load of 7.5 lbs. Suppose, however, that the particular shock absorber which was on hand had a deflection of only 3/32″ for this load; then the natural period of the panel would be approximately 600 cycles per minute and the transmissibility factor but 1/8. In such a case the above shock absorbed panel would show an amplitude of 0.024/8 or 0.003″, which would still be acceptable from the standpoint of satisfactory instrument performance.

Let us now take an example where a piece of shock-absorbing material was taken without due regard to its flexibility and had the deflection characteristic of, say, 0.01″ for this load. Then the natural frequency would be 31.1 per second or 1,866 per minute, our Transmissibility factor would become 14.2, or the original amplitude instead of being 0.024″ or less would become approximately 0.3″, with consequent fast destruction of the instruments. This example illustrates clearly, we hope, why we emphasize the fact that unless the above simple rules are followed, so-called "home-made" shock absorbers may do more damage than good. As a rule a $\frac{1}{8} \pm \frac{1}{16}$″ deflection will be found satisfactory on most installations.

It has been found that the most effective means for developing the elastic properties of a resilient material used as vibration insulation is to load it in such a manner that the principal strain in the material shall be shear. Particularly rubber has much greater ability to absorb vibration in shear than when stressed in any other way. Shear type mountings give an initial tension condition to the rubber and a characteristic of being many times as stiff radially as axially. This permits a suspension comparatively stable in any desired direction, yet "soft," with a low natural frequency in the direction of the greatest vibratory disturbances. At the same time hysteresis or internal friction of the rubber reduces the amplitude tremendously at resonance as compared with springs, and oscillations due to shocks when taxiing, etc., are quickly damped out. This action is shown by the dotted lines in the transmissibility curve (Fig. 3).

Summarizing, there are five points to be remembered when using plastic shock absorbers:

(1) The principal strain in the resilient medium should be shear.

(2) The resilient medium should be concentrated in units of convenient size in order to afford control of the unit load and unit deformation, thus fixing the natural frequency of the damper and thereby making it possible to entirely avoid resonance conditions.

(3) Anchorage must be obtained without impairing the vibration properties of the damper.

(4) The insulation units must be compact, and so designed as to require little space for installation.

(5) The insulation unit should be so designed that it may be manufactured in stock sizes, each size covering a limited and definite range of unit load and unit deformation; likewise natural frequency.

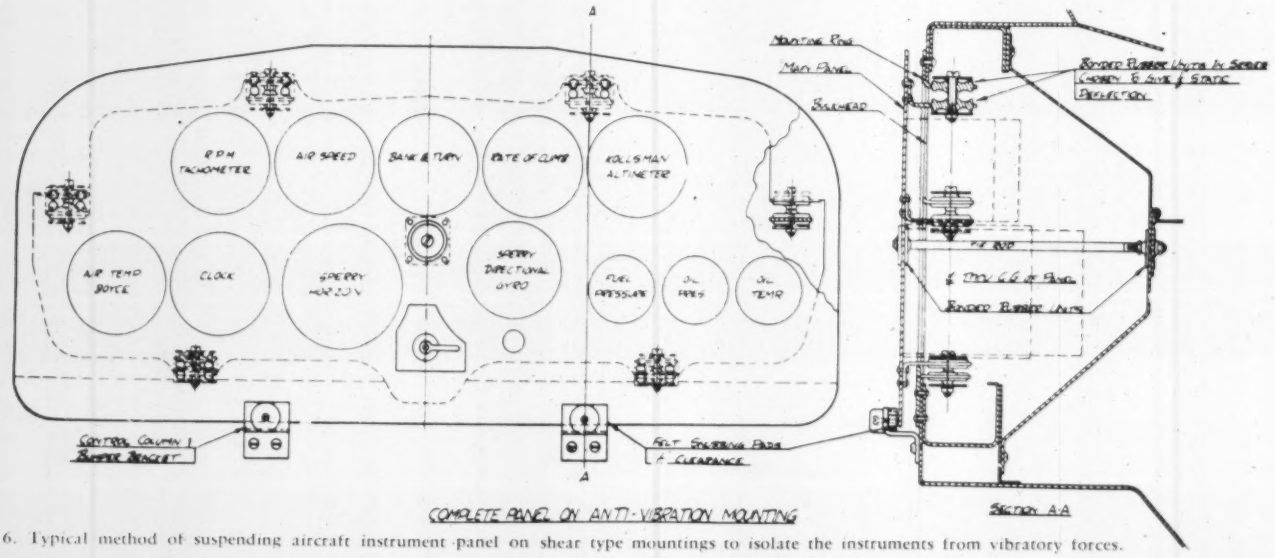

Fig. 6. Typical method of suspending aircraft instrument panel on shear type mountings to isolate the instruments from vibratory forces.

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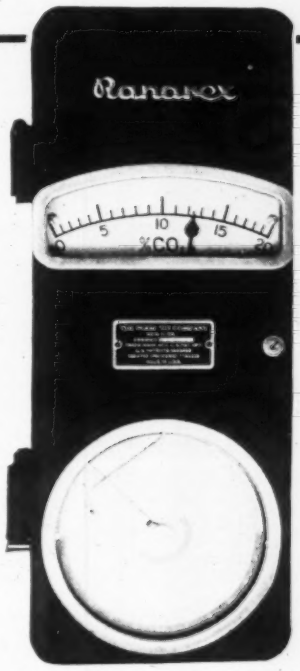

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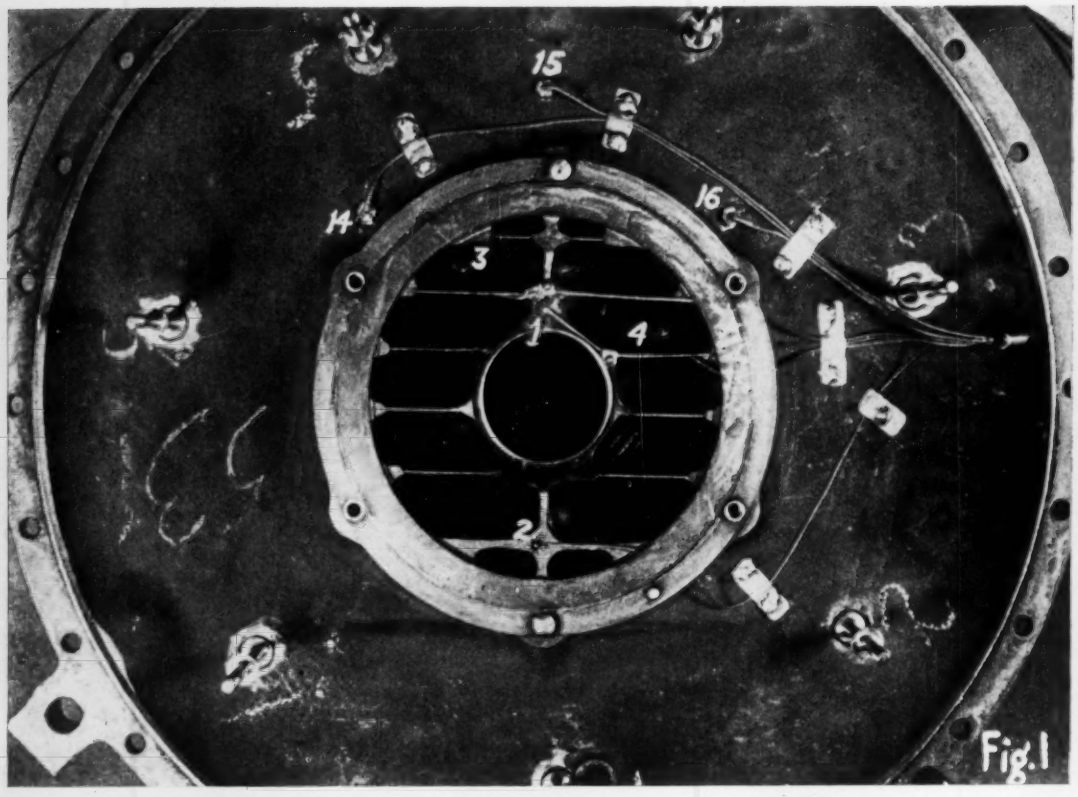


Fig. 1

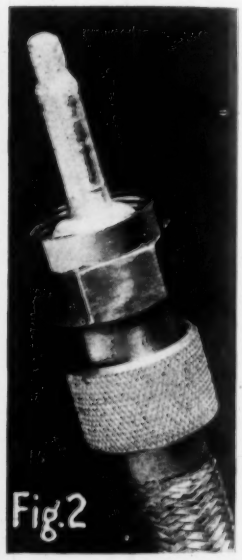


Fig. 2

Fig. 3

Fig. 1. Rear case of a twin-row engine equipped with sixteen flush-joint type thermocouples for a survey of temperatures of metal surfaces and of bearings.
Fig. 2. The new United Air Lines No. 6C-257 shielded thermocouple assembly for cylinder-head, oil or air temperatures.
Fig. 3. Cylinder-head insert for the UAL 6C-257 thermocouple.

Aircraft Thermocouples

By R. D. KELLY

Superintendent of Development, United Air Lines Transp. Corp., Chicago, Ill.

TEMPERATURE is one of the prime governing factors for the most vital items of aircraft equipment, and its accurate measurement is an absolute necessity under all operating conditions. Thermocouples of various types provide the most accurate-and-convenient means of determining the temperatures of cylinder heads, cylinder bases, fuel, metal surfaces, air (atmospheric, cabin and carburetor intake), oil lines, winshields, heating system, brakes, etc. In addition, the operating temperatures of such accessories as magnetos, spark plug electrodes, fuel pumps, vacuum pumps, exhaust systems, etc., must often be determined and the findings analyzed. For all these, the thermocouple is a versatile temperature measuring tool, weighing little, requiring no external source of power and having a minimum intrinsic lag.* The purpose of this article is to discuss briefly the various thermocouple installations which have been utilized by United Air Lines for routine operations and for special test flights.

Reasons for determining temperatures of some of the locations are as follows:

Cylinder heads, cylinder bases and spark plug electrode temperatures are used as indications of combustion conditions, which are functions of mixture, timing, etc. These temperatures must be kept within well-defined limits in order to preclude the possibility of cylinder head failure due to metal fatigue.

Excessive temperatures could result from improper mixture setting, improper cowl flap manipulation (cooling), or running under extreme power conditions without proper cooling or mixture control. In test work, these temperatures are prime indicators of preignition and broad indicators of mixture ratios.

*Of course, the use of protective sockets, tubes, etc., which are improperly applied, too heavy, of incorrectly-selected material, etc., slows down the response considerably.

Temperature can also be used as a rough indicator of detonation because detonation usually causes an increase in temperature over normal. In recent flight tests, detonation sufficiently severe to cause periodic violent vibration in the ship structure, was accompanied by an increase in temperature which soon stabilized. However, when preignition occurred, the temperature rise was immediate and exceeded the 600°F. scale maximum in a short time (30 to 40 sec.).

Fuel temperatures are, of course, measured throughout the fuel system on any given installation to insure that they are sufficiently low to preclude vapor formation due to boiling-off of the lighter ends.

Metal surface temperatures are measured throughout the engine in flight in order to study bearing temperatures, icing tendencies in the carburetor and induction system, etc. This type of installation is shown in Fig. 1 which illustrates thermocouple locations in the induction system of a twin-row aircraft engine.

Outside air and carburetor air temperatures are important with regard to engine cooling and power output. Knowledge of outside air temperature helps avoid ice accumulation on the plane. Windshield thermocouple installations are made for the purpose of studying methods of ice removal. Heating-system temperatures are taken in a study of the effectiveness of the heat transfer characteristics of the system. Brake temperatures evaluate the ability of the system to absorb the kinetic energy of the airplane without damage to drums, shoes or tires.

The types of thermoelements vary with the applications, as follows:

Type	Range °F.		Required Accuracy
Copper-Constantan	-300 to 570	±1°F. up to	570°F.
Iron-Constantan	-300 to 1400	±2°F. up to	500°F. ±1% above 500°F.

The iron-constantan couple (and leads) is most widely used in aircraft, because of low cost, ease of installation

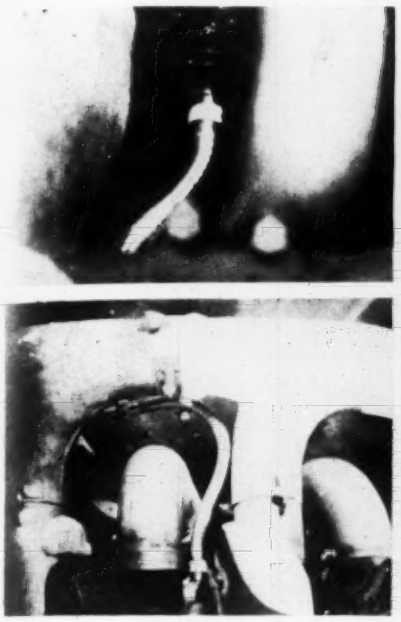


Fig. 4. Some idea of the limited-working-space difficulties are conveyed by these two views of a successful installation of UAL cylinder-head thermocouples.

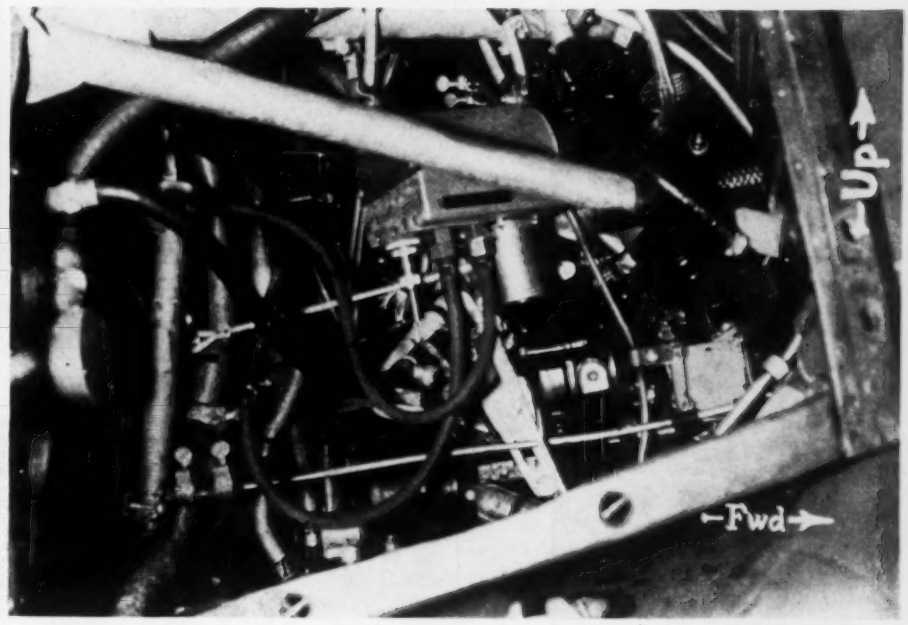


Fig. 5. Accessory section of one of the engine nacelles of a typical transport plane. (EDITOR'S NOTE: Readers in plants and labs on the ground who think their back-of-the-board troubles are tough, are invited to study this unique photograph—first of its kind ever published—and thank their lucky stars.)

and good serviceability. It is especially valuable for special test work where a potentiometer can be used as an indicator so that lead resistance is of no consequence. Its range is suitable except for special high-temperature installations such as spark plug electrode, exhaust tail pipe, etc.

The most widely used type (form) of thermocouple assembly is the gasket type. The leads are silver-soldered to a gasket of copper or other material. The gasket has an extension or flange to which the leads are fixed. The wires are spaced about 7/32" apart on the gasket flange and are equipped with quick disconnects about 6" from the flange of the gasket. The gasket is then located under a spark plug, cylinder hold-down bolt, or whatever location is being studied. This type has the following inherent disadvantages for routine service:

(1) The wire leads or the gasket flange break readily in service.
(2) They are damaged easily in handling.
(3) They present an unworkmanlike appearance.
(4) It is impractical to attempt to shield them mechanically or electrically.
(5) Uniform seating of the gasket is critical and freedom from corrosion important. In routine line service, these factors call for a great deal of attention.

To overcome these difficulties, United Air Lines developed the plug type thermocouple shown in Figs. 2, 3 and 4. This type has wide application for cylinder head temperatures, oil temperatures and air temperatures during routine flight operations. Copper-constantan are the thermoelements in this case because it is desirable to restrict to two ohms the resistance from the engine nacelle to the cockpit. Iron-constantan cable meeting this requirement would make the installations too heavy. This unit has been proven by years of service on United Air Lines and gives consistently accurate readings over an engine change period of 725 hours with a minimum of service attention.

This plug type of thermocouple is also used for outside air temperatures and carburetor air temperatures. It is interesting to note that in the case of the outside air temperature the indication on the cockpit instrument of a United Air Line Mainliner will be from 3 to 5° higher than the actual outside air temperature due to the heat resulting from the adiabatic compression and friction effects of a 180-mile-per-hour air-stream against the thermocouple.

The carburetor air thermocouple must be located to give mean indications for "full cold," intermediate and "full hot" positions of the carburetor heat valve. Heated carburetor air is utilized for the prevention and/or the removal of induction system icing. With the type of carburetor air heaters in common use, considerable stratification takes place with as much as 100° F. difference existing from point to point over a cross-section of the air duct. Therefore, the thermocouple must be located to show the most representative temperature. This location is determined by test with several thermocouples being installed across the area. This carburetor air temperature study is of further importance in that the location of the automatic mixture control unit of the carburetor must also be placed in a location so it will always be subjected to a representative temperature. The automatic mixture control unit is a temperature-sensitive device and if it is located in a high-temperature region the carburetors will operate unduly lean.

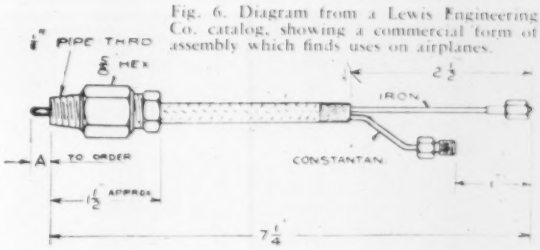


Fig. 6. Diagram from a Lewis Engineering Co. catalog, showing a commercial form of assembly which finds uses on airplanes.

The flush joint type of thermocouple is generally used for metal surface temperatures. It consists of a stud bolt drilled through to the threaded end, with the thermocouple wires brought through and flush soldered on the threaded end. This end is then dressed down, and is used to make the contact on the surface desired. Twenty-eight gage wire is used most commonly for this purpose. Sometimes the wires are simply silver soldered together, dressed down, and suitably fixed to the surface being studied. This type is used in difficult locations (Figs. 1 and 5) where severe restrictions exist as to space, etc.

For cylinder base thermocouples the tips of the wires are covered with a soft metal sheath, and these are peened into the radius of the cylinder mounting flange and are spaced about 7/32" apart. This installation is awkward to make, however, and does not stand up well in service. For extended tests, therefore, gasket couples are placed under the cylinder hold-down bolts and calibrating data taken, to correlate the two types.

One of the most difficult temperatures to take is that of the fuel. The use of any restriction in the fuel line is not advisable, hence, as a general rule a thermocouple either in the form of a simple wire junction or a gasket type unit is placed on the outside of the fuel line and the line, together with the thermocouple, is wrapped thoroughly with

asbestos tape and then covered with waterglass. It has been found that the observed temperature is within 3° of the actual temperature of the fuel in the line.

In taking blower rim temperatures of fuel-air mixture the wire junction type of couple is used. This is prepared in a suitable boss which must be leak-proof. This boss is inserted in outlets provided around the periphery of the blower rim. See Fig. 6.

Aircraft thermocouple installation problems probably are common to the installation of any temperature measuring device. The space in which one can work is greatly restricted (see Fig. 5) and once an installation is complete no corrections can be made in flight. Failure of any part of the temperature equipment means discontinuing flight where testing is being done, and possibly delaying a trip in routine service. No ship would be knowingly dispatched with defective thermocouple equipment since it tells the pilot if his engine is running satisfactorily. Thermocouples must be installed with due consideration being given to ease of installation and removal, interference with structure, electrical interference and any heat interference.

The problem of reading temperatures in flight presents difficulties, especially where large groups of temperatures are read for test purposes. The physiological effects of high altitude and rough air and the mechanical effects of ship attitude, ship vibration, etc., all must be taken into consideration in preparing the set-up of instruments which will work with the greatest reliability and ease of reading. For test work of a fairly simple nature the pyrometer potentiometer is generally used in conjunction with a multiple-position switch. With a fair degree of speed by the operator, twenty-eight positions can be read at an average rate of about eleven readings per minute. This time of reading, of course, varies: any change of conditions must incorporate suitable time for stabilization; and where extreme vibration is present, it takes a skilled operator to balance and read the potentiometer in spite of the galvanometer needle swinging all the time. The potentiometer is generally protected as much as possible from vibration by means of a soft rubber pad, or blanket, or some similar arrangement.

Autographic potentiometers providing continuous records on paper charts are occasionally used. However, they have been found to be a trifle slow since the readings take about 9 seconds. These instruments are bulky and complicated but generally perform well and give good accuracy.

For tests of a comprehensive nature, indicators of the direct-reading millivoltmeter type are utilized. These must provide immediate response with a minimum of pointer overswing. Millivoltmeters are generally used with an automatic switch selector arrangement that is coupled in with photographic apparatus for recording the data. Fig. 7 shows one typical installation of this type in United Air Lines' Mainliner and illustrates the general type of set-up used. This method is probably the most efficient, practical means

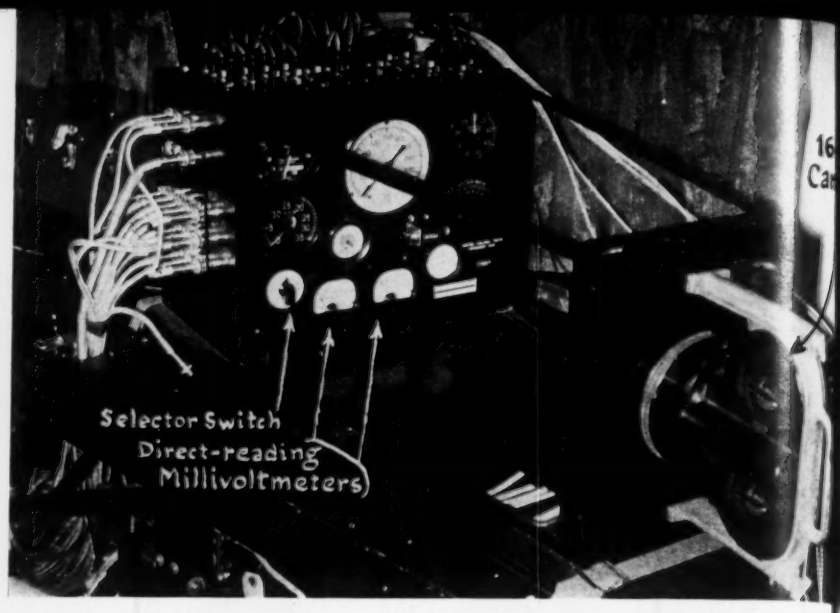


Fig. 7. A typical UAL "data box" and camera for recording test data in flight. Only the temperature-measurements section of the "data box" has been lettered-in.

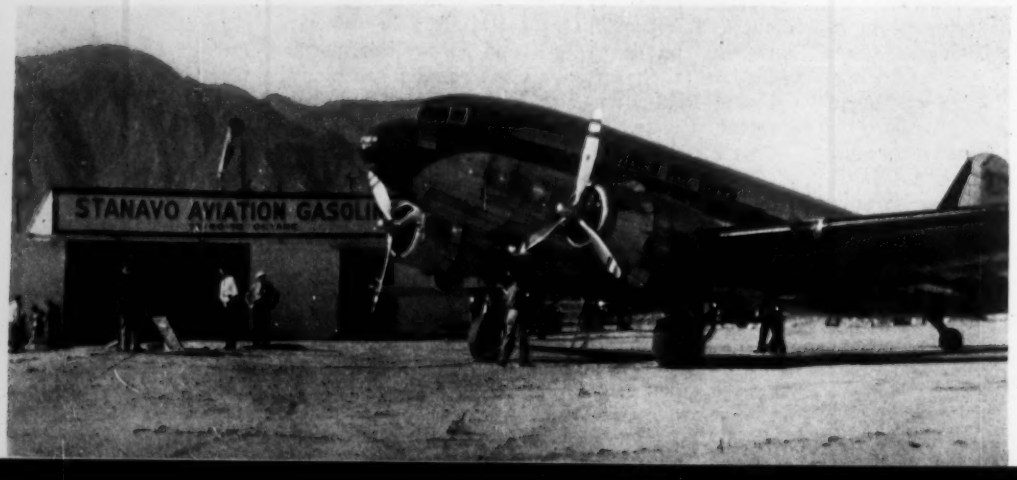
of accomplishing long detailed flight test programs and it seems to be least affected by flight conditions. When it is considered that flight tests often are run within 1000 feet of the earth's surface with a nose high ship attitude, one wing low, coupled with pitching, rocking and general bumping about associated with such low-altitude work, it can be appreciated that it often would be extremely difficult for an operator to fix his eyes on an instrument dial and obtain accurate readings. The photographic method is the most desirable under these circumstances, since the only attention required is the turning off and on of the recording equipment. This type of equipment, moreover, does not fatigue the operators. Test flights, as conducted by United Air Lines, often are from six to eight hours in duration at altitudes ranging from 1000 to 30,000 feet. At the higher altitudes especially, although the air is smooth, the effects of oxygen deprivation cause inaccuracies to creep in although the operator himself may feel that his work is precise. Furthermore, his response to change of conditions is slow and the work proceeds slowly.

During a recent flight test program, United Air Lines installed fifty thermocouples in each nacelle of a Douglas DC-3 twin-engine transport, as well as other special power plant test equipment such as flowmeters, torque meters, detonation indicators, etc. The airplane was flown for 175 hours with this equipment installed, and was operated all over the southwestern section of the United States, which meant that it was far from repair facilities a good portion of the time (see Fig. 8). Spark plug gasket couples were used for this test work, and it was found that, as mentioned before, corrosion and breakage, rather than instrument troubles, were the major factors contributing to the unreliability of the temperature recording system.

Fig. 7 was taken during an actual flight test. Approximately 100,000 separate frames of data were taken by the 16-mm. motion picture camera mounted on the test panel. Each frame shows all necessary power information as well as the correlating temperature data for the instant when it was taken. In addition the millivoltmeters were visible at all times and this enabled the operators to detect, within 15 to 30 seconds, any engine conditions which would have caused an actual mechanical failure of the engine had they been allowed to persist. This system further enabled the operators to watch the development of this condition, take pictures of it and stop it before damage of a hazardous nature was imminent. The engine actually was allowed

(Continued on page 308)

Fig. 8. One of the UAL test airplanes refueling at a desert station during the course of a four-month test period in the Southwest desert areas.



Chief Test Pilot Burrell with one of his arrangements for recording aircraft flight data on 16-mm. film. In this set-up, the camera takes a direct picture of the panel. Mr. Lescher's article describes the Burrell-Rudnick panel with the camera mounted IN the panel itself to take a reflected image of the panel.

Test Flight Data Automatically Filmed

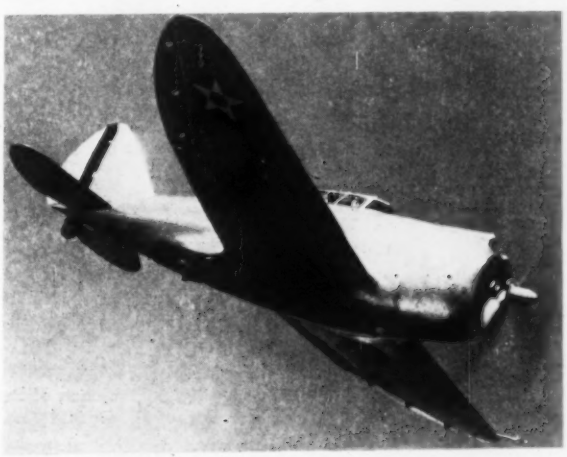
By GEORGE W. LESCHER

Executive Engineer, Republic Aviation Corp., Farmingdale, N. Y.

DUPLICATE instrument panels—one in the cockpit and one in the interior of the ship—plus a motion-picture camera, are expediting the testing of the airplane products of Republic Aviation Corporation, such as the Company's P-43 "Lancer" pursuit-interceptor being manufactured for the U. S. Army Air Corps.

By means of a unique process developed by George W. Burrell, chief test pilot at Republic, and Ben Rudnick, the Company's photochemist, data-taking during test flights has been made complete and entirely automatic, hence accurate. The process involves photographing *all* flight instruments while the plane is being put through its paces in the air. On their second instrument panel Burrell and Rudnick mount temperature and air-speed indicators, chronometers, engine gages, etc., to a maximum of sixty-odd different devices. Also mounted *in* the panel is the lens of an ordinary 16-mm. motion-picture camera. About four feet from the panel, a special front-surface mirror reflects the instrument images and is photographed by the camera, utilizing fluorescent light for which current is supplied from the plane power plant. The camera drive is geared to expose one frame per second.

With this complete rig, Republic's engineer-pilots and aerodynamicists are testing all of their experimental aircraft with great speed and facility. Second-by-second recordings of all instrument readings are made for the duration of the flight (the camera is loaded for a full hour's picture-making). The completeness of detailed data effectively short-cuts the repetitious flying usually required to bring back an instrument recording of a flight-testing program.



The new single-seat P-43 "Lancer" developed by Republic (with the aid of the flight-data-recording panel) for attacking bombardment groups at altitudes exceeding 25,000 feet. This fighter is "little brother" to the still newer "Thunderbolt."

Common practice in the aircraft industry has been to require the pilot to note instrument readings, from his cockpit instrument board, while flying the plane and otherwise busily engaged. Pilots could observe and record only one or two instruments at one time. Numerous flights were required for a full collection of data. The correlation of a wide variety of data, such as outside temperature, air-speed, cylinder-head temperature, altitude and engine oil temperature and pressure, could never be obtained simultaneously because of the inability of the pilot to record so many different readings at one time. All flight data had to be gathered piecemeal, laboriously — sometimes inaccurately, since a pilot's readings were naturally affected by human frailty, fatigue, altitude strains, etc.

With the Burrell system, as many as sixty inter-related instrument readings are obtained simultaneously. The photographic work is so excellent that the photographic series can be enlarged on the screen to a size which permits all instruments to be read accurately and easily. The reel can be run and re-run for different types of data-study, instead of flying and re-flying the plane, as was required under previous procedure.

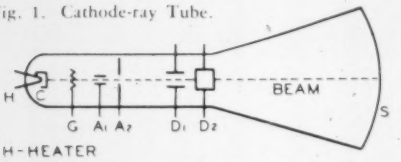
The lighting, the type of film, the developing process, the instrument-arrangement in the panel and the reflecting surface—all have contributed to the success of Burrell's system. He has made it freely available to other aircraft manufacturers. As far as is known, the best previous recording of instruments on film has been to photograph fewer than a dozen on 35-mm. film, a type of camera and film too bulky to be tucked into a modern pursuit airplane.

Calibrating Tachometers with the Oscilloscope

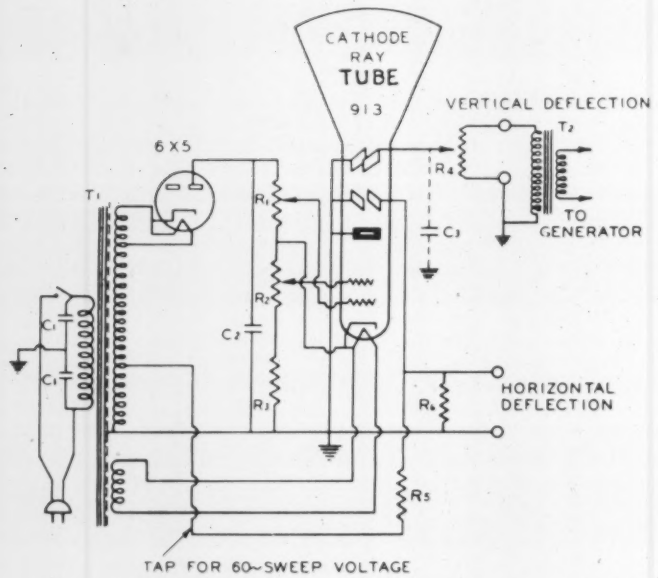
By EDWARD M. GLASER
Kollsman Instrument Div., Square D Co., Elmhurst, N. Y.

VERSATILITY, the outstanding characteristic of the cathode-ray oscilloscope, has made this relatively inexpensive device supplant the delicate and expensive string oscillograph in numerous laboratories and has made it become standard equipment in the electrical experimenter's hideout or radio man's shack. The heart of the cathode-ray oscilloscope is an electronic vacuum tube with three elements for controlling and focussing a beam of electrons emitted from a hot cathode. (See Fig. 1.) With zero voltage on both sets of parallel deflecting plates, the spot remains in the center of the screen. By applying various voltages to these plates we may deflect the spot, the amount of deflection being proportional to the deflecting voltage. In general, horizontal deflection is used for "sweeping" or providing a zero axis; and vertical deflection for a voltage corresponding to the changing values of the phenomenon being studied.

Fig. 1. Cathode-ray Tube.



H-HEATER
C-CATHODE
G-GRID
S-SCREEN
A1-FOCUSING ANODE
A2-HIGH-VOLTAGE ANODE
D1-D2-DEFLECTION PLATES



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C2 - 2 MFD. 600 W V
C3 - 0.5 MFD. OPTIONAL (WAVEFORM CORRECTION)
R1 - 50000 Ω POTENTIOMETER (BRILLIANCE)
R2 - 100000 Ω POTENTIOMETER (FOCUSING)
R3 - 250000 Ω 1/2W
R4 - 500000 Ω POTENTIOMETER (GENERATOR DEFLECTION)
R5 - ADJUST FOR FULL SCREEN DEFLECTION
R6 - 5 MEG. 1/2W
T1 - SHIELDED POWER TRANSFORMER
T2 - 1:10 HIGH IMPEDANCE STEP-UP TRANSFORMER
913 - CATHODE-RAY TUBE
6X5 - RECTIFIER

Fig. 2. Typical Oscilloscope Circuit for R.p.m. Measurement.

One of the oscilloscope's applications is the measurement of frequency by comparing two voltages having the same frequency, or integral multiples of the same frequency. (If the two voltages are not so related, the images on the screen will drift. If the rate of drift is too fast to be timed, the relation of the unknown frequency to the known frequency could not be determined.)

The ability of the oscilloscope to compare two frequencies visually permits us to measure r.p.m.—which is but another name for frequency. We measure r.p.m. by comparing an unknown frequency to some standard frequency which may be obtained from an accurate tuning fork or oscillator, or simply from the 60-cycle supply. The large light and power systems have installed automatic frequency regulators and their a-c. supplies constitute a good standard for tachometer calibrations because the usual frequency variation is negligible for this purpose. In measurements conducted during the last two years, the line frequency error was never found to exceed 0.25% and, in the vast majority of readings, the error was unreadable, being less than 2 r.p.m. More on this subject later.

Fig. 2 shows the method of using the 'scope for setting the tachometer test stand or any variable speed device to known points.* A small a-c. generator is attached to the shaft of the test stand. The generator output is fed to one set of deflection plates—through a step-up transformer if the voltage is insufficient. The line voltage is fed to the other set of plates, usually through an isolating transformer for reasons of safety. (In Fig. 2, the voltage is derived from the power transformer, a tap being provided on the high-voltage secondary.) The two voltages are thus compared on the cathode-ray screen so, by varying the speed of the stand, they may be brought into synchronism at any one of a large number of test points. The principal points are given in Table I together with the harmonic relationships based on a 60-cycle line. For a 50-cycle line, multiply all points by 5/6, etc. Fig. 3 shows some of the patterns obtained. For the complete list, it is imperative to have some sort of tachometer connected as many of the points have complex patterns which are not readily recognized. This tachometer need not be accurate because corrections

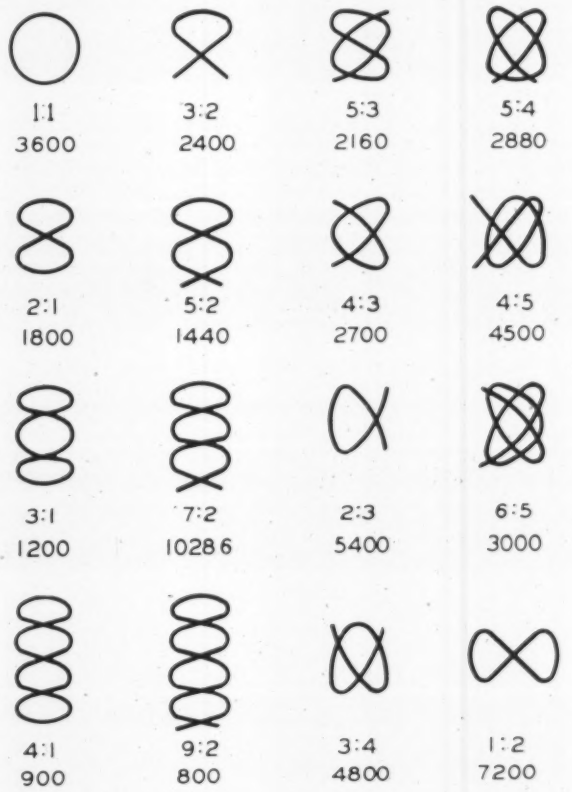

Fig. 3. Evolution of Patterns at Various Ratios and Speeds.

*These points are the speeds at which the screen image stands still.

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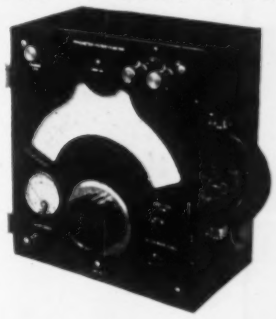

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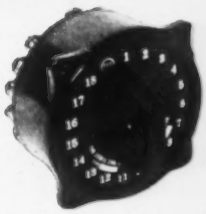

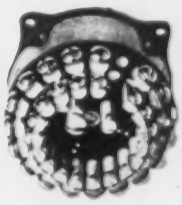

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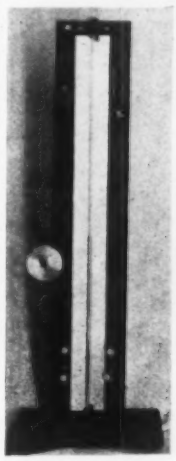

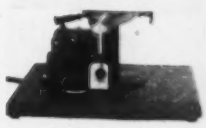

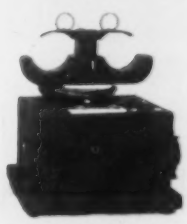

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TABLE I—TEST POINTS FOR A FREQUENCY OF 60 CYCLES

Ratio	R.p.m.	Ratio	R.p.m.	Ratio	R.p.m.	Ratio	R.p.m.
6:1	600	5:3	2160	9:10	4000	5:8	5760
5:1	720	8:5	2250	8:9	4050	3:5	6000
9:2	800	3:2	2400	7:8	4120		
4:1	900	7:5	2570	6:7	4200	Less obvious points:	
7:2	1028.6	4:3	2700	5:6	4320		
3:1	1200	5:4	2880	4:5	4500	10:3	1080
5:2	1440	6:5	3000	7:9	4630	13:4	1107.7
9:4	1600	7:6	3084	3:4	4800	11:4	1309.1
2:1	1800	8:7	3150	5:7	5040	12:5	1500
9:5	2000	9:8	3200	7:10	5400	9:7	2800
7:4	2057.1	1:1	3600	2:3	5400	10:9	3240

may be made on the spot from the simple, or obvious points. However, the readings should be consistent or a certain amount of ambiguity will result where two points are close together.

With an oscilloscope having a large tube (say 5") no difficulty should be experienced in obtaining the complete list of Table I; an apt student should obtain many more. With a 1" tube some of the points may be hard to detect. The smoothness of the stand will have a lot to do with the operator's ability to get the points and hold them: the more complex the pattern, the harder it is to perceive and to hold. Only a few minutes' practice will be required to recognize any of the simpler points.

HOW THE 'SCOPE OPERATES

To start, we assume that the generator delivers a smooth wave-form containing no harmonics (a sine wave). The simplest point is the one at which the two frequencies are the same (60 cycles) and the ratio is 1:1. If the generator has a 2-pole winding, the stand will be running at 3600 r.p.m.; for a 4-pole winding, the speed will be 1800, etc. according to the formula: $\text{r.p.m.} = 7200/p$ where p = number of poles.

Assume that the generator is connected to the vertical posts of the oscilloscope and the line to the horizontal posts. The generator alone will cause the beam to draw a vertical line as in Fig. 4(a); the 60-cycle line a horizontal line as in 4(b). Fig. 5(a) represents the generator voltage which

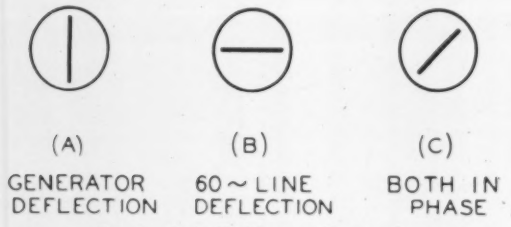


Fig. 4. Basic Oscilloscope Patterns.

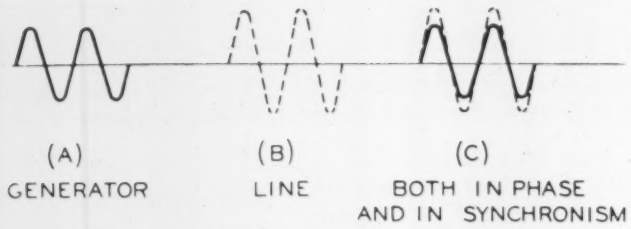


Fig. 5. Voltage Waves Producing Patterns of Fig. 4.

Fig. 6. Phase Angles 1:1

Fig. 7. Phase Angles 2:1

causes the trace of 4(a). 5(b) shows the a-c. line voltage which produces 4(b). Remember, we are considering the case where both frequencies are equal.

If both voltages are applied simultaneously and both start at the same time (in phase), the result will be a slanting line as in Fig. 4(c). The corresponding voltages are shown in 5(c). A 45° line will result when the voltages are equal. If the two voltage waves are not in phase, the pattern will no longer be a line, but an ellipse. Fig. 6 shows the range of patterns obtainable with different phase angles. Any one of these pictures, when steady, indicates unison—a state of synchronism—and, in this case, 3600 r.p.m. Similar reasoning applies to all other points; example, the 2:1 point, 1800 r.p.m. shown in Fig. 7.

All patterns shown are for 60 cycles on the horizontal posts and the generator on the vertical posts. If the leads are reversed so that the a-c. line is connected to the vertical posts, the pictures will be rotated 90°. (The X and Y axes will interchange).

Points below 10 cycles, or 600 r.p.m., are not included in Table I because of the difficulty of interpretation due to flicker. However, it is possible for the experienced observer to get points down to 500 r.p.m. Flicker is also bothersome in the vicinity of the simple points. The worst case is at 3600 where, for about 400 r.p.m. either side of synchronism, the flicker prevents recognition of other points. At the 2:1 points (1800 and 7200) the region of interference is about half as wide: 200 r.p.m. on either side.

Most cathode-ray tubes take from 75 to 250 volts on the deflection plates to give full-screen deflection. Therefore, at the lowest speed at which it is desired to set the stand, the voltage must be sufficient to give a reasonable amount of deflection—say ¼ to ½ screen. If the generator is incapable of supplying this voltage, a step-up transformer or amplifier must be used. At Kollsman, we use a type 377G 4-pole electric tachometer generator which is used with an electric tachometer. At 1000 r.p.m. the generator delivers approximately 6 volts, which is stepped up to 60 by a 1:10 step-up transformer. The transformer is of low-burden design; that is to say, it alone draws little power from the generator. Since no "power" to speak of is required for deflection of the cathode-ray beam, the transformer may be considered as operating without load. The larger and more expensive oscilloscopes, which are usually called oscillographs, nearly always have self-contained amplifiers. These amplifiers always have a gain greater than 10 times and often reach several hundred times, so that no transformer is required.

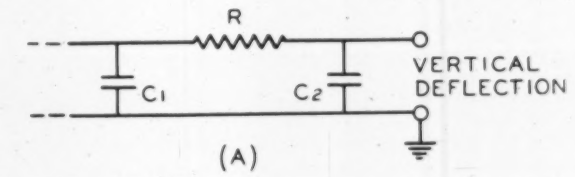
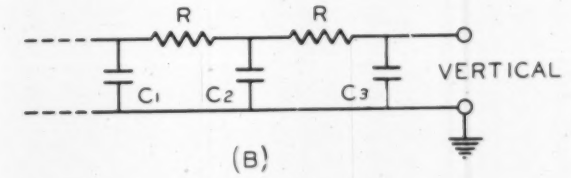
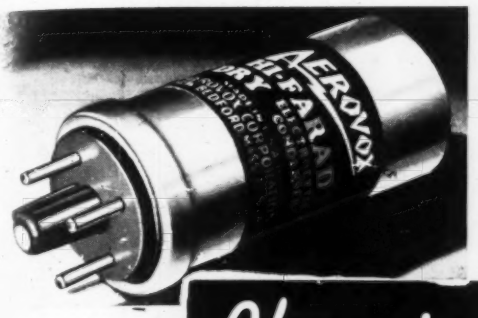


Fig. 8. Filters for Improving Wave-form.



In presenting the subject of patterns we assumed each voltage to have a sine wave-form. This was necessary to give us smooth figures, the easiest to recognize and reproduce. The a-c. supply, in the large industrial centers where most *Instruments* readers work, has a nearly-perfect sine curve wave-form. However, such is seldom the case with small generators. If the available generator has a rough wave-form (say more than 15% harmonic distortion) it is advisable to use a low pass filter to attenuate the harmonics, thus making the wave-form approximate a sine curve. This filter may be simple, as shown in Fig. 8. The dual capacitor and resistor shown in Fig. 8(a) will suffice



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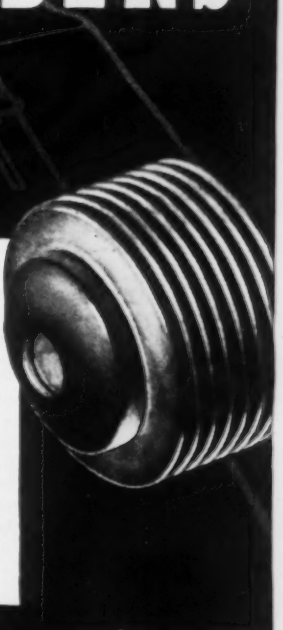

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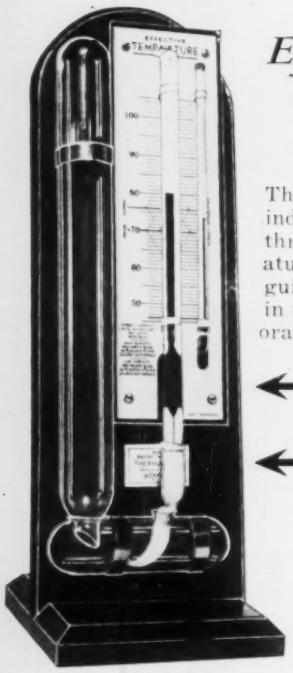

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The Bailey-Parsons Therhumiter indicates the *combined effect* of all three atmospheric factors—temperature, humidity and air motion. As a guide to proper working conditions in industrial plants, workshops, laboratories, hospitals, offices, etc., it is indispensable. The EFFECTIVE TEMPERATURE indication on the red spirit thermometer in center (see illustration) has been achieved by combining both wet and dry bulbs on a single stem. Write for descriptive bulletin BP. The Bailey-Parsons Therhumiter, furnished in wall or desk types, is **manufactured and distributed exclusively by**

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Manufacturers of a complete line of

THERMOMETERS, HYDROMETERS and HYGROMETERS.

in most cases although the smoothing will be more nearly perfect with the 2-section filter of Fig. 8(b) which is recommended for generators having bad wave-forms. Increasing the values of the components will also aid the filtering.

NOTES ON COMPONENTS

In many cases, C_1 may not be required.

Values in Fig. 8(a):

For a low-voltage generator:

$C_1 = C_2 = \frac{1}{2}$ mfd. $R = 20{,}000$ ohm, 1 Watt.

For a high-voltage generator, or in the secondary of a 1:10 step-up transformer:

$C_1 = C_2 = 0.1$ mfd. $R = 30{,}000$ ohms.

Values in Fig. 8(b):

$C_1 = C_3 = \frac{1}{2} C_2$ for optimum performance

Values of R and C_1 the same as in Fig. 8(a).

When a step-up transformer is used, a single 0.5-mfd. capacitor across the secondary may suffice. Otherwise, the reduced values shown in the figure must be used or the attenuation will be too great. When the correct values are used for the particular set-up, the amplitude of the pattern will remain constant for wide variations in speed, obviating the need for constant deflection adjustment. Filter chokes are not recommended for this filter as the voltage characteristic will probably be peaked. Use of a choke causes too sharp a cut-off when operating over a range greater than 3 to 1.

In cases where greater accuracy is required than may be obtained from the power line, a tuning fork may be used. Electrically-driven forks have accuracies of the order of 0.005%. For checking the accuracy of a 60-cycle fork, for instance, an amplifier feeding an electric clock may be used, in which case tuning-fork time may be directly compared with standard time. If kept at constant temperature, a good fork will keep time to within a few seconds a day. One second per day is one part in 86,400, or 0.0012%.

Good aircraft tachometers have error limits of 10 r.p.m. up to full-scale. The standard may be considered satisfactory if the errors are held to about 2 r.p.m. at 2000 r.p.m., which is 0.1%. The 60-cycle supply in our district is held within that accuracy during most of the workday. We notice that the greatest variation occurs at starting time and quitting time when there are large sudden changes in power load; also with the approach of a sudden "blackout" thunderstorm which also causes an unexpected peak. It should be remembered that the *average* accuracy is "perfect" because electric time must be maintained accurate to a few seconds. Over a longer period of time (say six hours) it must still be within a few seconds. The large utilities pride themselves on regaining daytime droops so that their time is accurate to one second at midnight every night. Therefore, if an accurate calibration job is undertaken, an average of several calibrations at different times of the day will tend to wipe out any instantaneous inaccuracy.

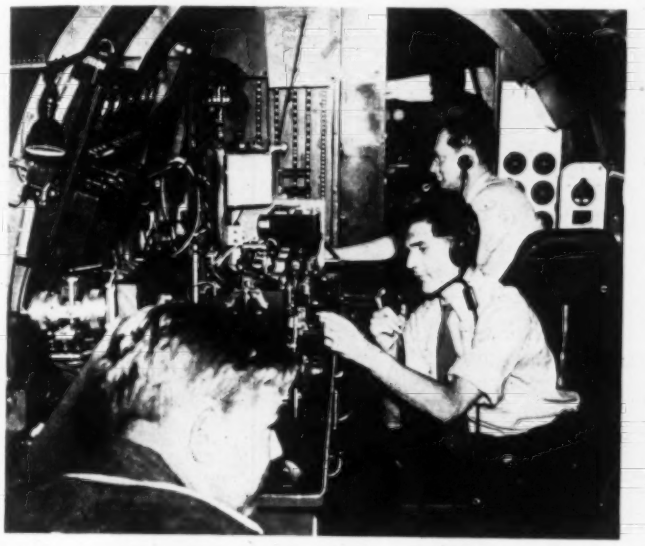
Another use of the oscilloscope is testing accelerometers. It was found convenient to use a turntable running at known speeds. The speeds are obtained as described above, by getting the turntable almost up to speed with a good tachometer, then turning to the oscilloscope. Accelerating slowly, the switch is opened just as the image becomes stationary.

The Front-cover Photograph

TAKEN during the flight-testing of the Boeing 307 Stratoliner, shows the unique methods used by the company for recording test data in its various types of airplanes. On the special instrument board installed in the passenger cabin, are sixty-five instruments: twenty-eight regular aircraft instruments and thirty-seven manometers for recording pressures in various systems. This complete board is photographed at intervals during a test, recording data faster and more accurately than could a dozen observers. Sometimes as many as eighty pictures are taken during an hour's test flight. Data are transcribed directly from the developed negatives, run through a viewing machine, and photoprints are made for permanent records.

Two More Flying Laboratories

NOT so many years ago the very idea of a flying laboratory was news. Today the news interest lies in the particular field of research for which "another flying lab" is equipped. In this issue we show glimpses of several: Boeing's (cover) is described on the facing page; others in the articles by Kelly and by Lescher; here are two more:



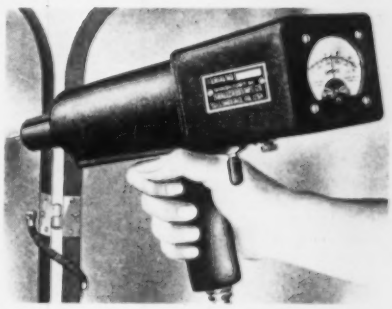
The above photo taken in the cabin of the Sperry Gyroscope Co.'s Air Lab (a Lockheed with twin Wrights) shows also a glimpse of the cockpit. In the nose of this ship, forward of the pilot's instrument panel, there is a large light compartment with space for a table, chair, recorders and room for working behind the panel itself. Field of research: aircraft instruments.

And here is a typical photo taken during a flight test of a Glenn Martin airplane. This aircraft manufacturer converts each new model into a flying lab. Field of research: all effects of various flight conditions on structural members, on other components, on auxiliaries, etc.

Chicago Society for Measurement and Control

Make reservations now for Monday, Nov. 10: "The Economic Value of Power Plant Instruments" will be discussed by M. D. Forty, Results Engineer of Commonwealth Edison Co. St. Clair Hotel, 162 East Ohio St. Dinner ($1.25) at 6:30, meeting at 8 sharp. Come to the meeting if not to the dinner. Carl Hope, Exec. Sec'y, 2626 W. 31st Blvd., Chicago.

A NEW ELECTRIC BOND TESTER



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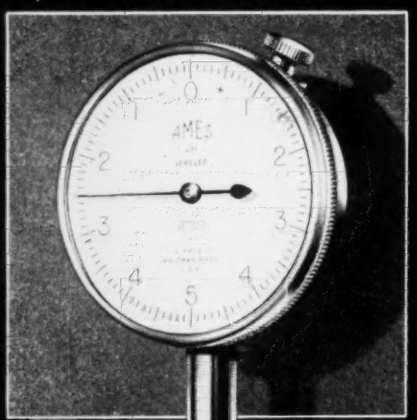

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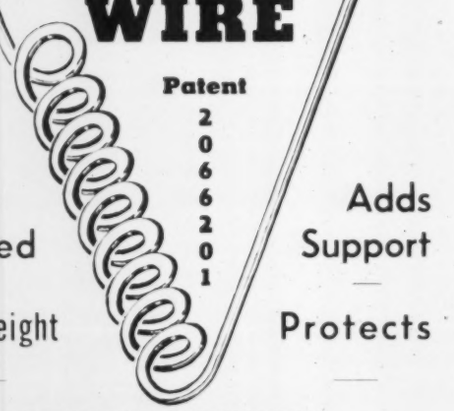

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Aircraft Thermocouples

(Continued from page 300)

to proceed to the point of a failure in one of the combustion chambers but as soon as the failure had progressed to the point where sufficient data had been recorded for analysis, the engine was stopped to prevent damage of a major nature to either the engine or the ship structure. As a point of interest, the failure concerned was one of preignition. It is obvious that an instrument with excellent response characteristic is of vital necessity.

The standard ships in service today have liberal thermocouple installations—cylinder heads, outside air, carburetor air, oil lines, etc., all being so equipped. That our ships are checked carefully before dispatch is well-known, but even the readers of *Instruments* may not realize that this checking is mainly for temperatures, to insure the proper functioning of the various elements, and in particular the power plant. All indications now are that in the future much more extensive use of the thermocouple will be common, particularly for power plants, in order to operate all equipment in the most efficient manner.

Two Needles Are Better Than One

(Continued from page 282)

supplement the beam signal with the visual aid of the two needles. But, say airline officials, both navigational aids are not necessary. In the projection of new airline routes there are many cities in need of air transport service between which no radio beam has been established. Radio frequencies are now so numerous in the U. S. that there are areas over which new airline routes could be advantageously established where possibly a beam could not be projected without seriously interfering with transmission and reception of stations already established. Here, predicts Luckey, the dual direction finder could take the place of the beam.

Luckey forecasts that the dual direction finder can be used to guide ships in for landings, particularly effective in landing airliners after an "instrument approach." This is a navigational procedure whereby a pilot lands a ship although the ceiling may be only from 300 feet to 1,000 feet, depending on safety limitations individually prescribed by each airline, with approval of the Civil Aeronautics Authority, for each airline airport. As a ship may approach an airport for a landing, flying above the overcast and out of sight of the ground, point of orientation for the pilot is a radio range station or beam station which is located near the airport. After the pilot orients himself over the range station he works a "problem" of prescribed turns and maneuvers which brings him under the overcast at a safe altitude and in position to land.

Luckey forecasts that an improved approach procedure could be worked out. (This is shown in Fig. 3.)

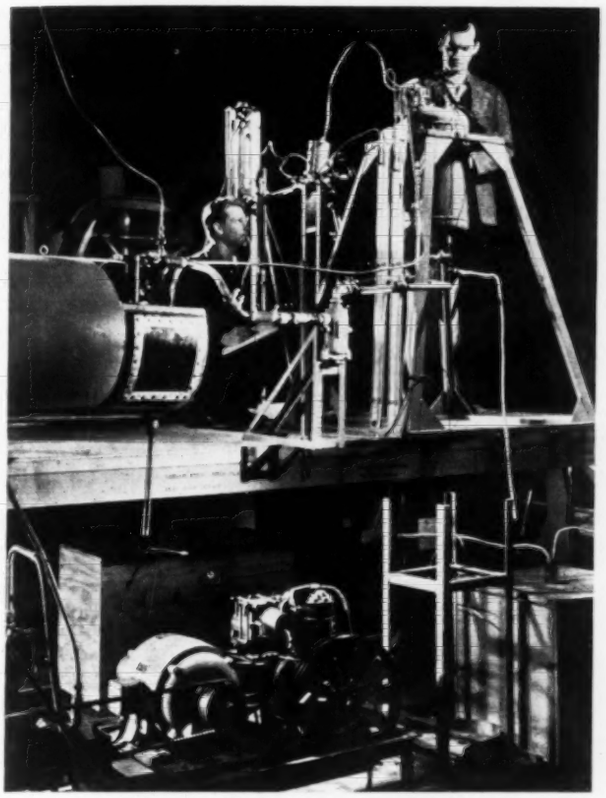
A landing procedure of this nature would take much less time than instrument approaches now take. Luckey figures it will reduce the approach time from an average (on Braniff airways) of approximately 13 minutes to about an average of 4 minutes.

Luckey points out still another benefit: eliminating what airmen call flying a "bowed" course. Flying from one city to another, pilots often have to contend with a cross wind which, even with the single-needle direction finder, causes the ship to drift and fly a "bowed" course. Airmen know that a "bowed" course is a longer course. Therefore it wastes time and operating costs.

Proud that Braniff will be the first airline to have the new direction finder, Luckey has added a trophy to his souvenirs. It's the tobacco can top on which is scratched the autograph of Reeder G. Nichols.

INDUSTRIAL INSTRUMENT SERVICE
CLAUD S. GORDON CO., Cleveland—Chicago—Indianapolis

Testing a Complete Fuel System



HERE'S the thoroughgoing manner in which the Vultee Aircraft Co. tests the complete fuel system of one of its airplanes. The system is set up and subjected to conditions simulating certain flight conditions, while flowmeters and pressure and vacuum gages provide the data on its performance.

Photographic Recording of Transients from Cathode-ray Tube Screen

(Communication from Allen B. Du Mont Labs., Inc., Passaic, N. J.)

RECORDING transients from the screen of the cathode-ray tube is usually accomplished by photographing the screen at the right moment. Since the signal occurs only once, a single trace of the spot must give the required negative density. The maximum writing-rate which may be recorded is limited by the emulsion speed, the magnification of the lens system, the speed of the lens system, and the accelerating potential and the beam current of the cathode-ray tube. Du Mont engineers have determined empirically the following :

With a lens opening of f:4.5, accelerating potential of 1000 volts, willemite screen, magnification of 0.5, and a panchromatic emulsion having a Weston speed rating of 24, writing-rates as great as 1500 inches per second will give satisfactory negative density.

From these empirical data it should be possible to calculate the maximum writing rate which may be photographed when photographing a transient with a still camera (using a single-sweep circuit) or when using a moving-film camera. Particularly suitable for this kind of work is the single-sweep circuit of the Du Mont Type 175-A oscillograph with its long-persistence screen teletron operating at a high accelerating potential for vivid trace.

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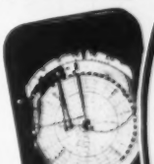

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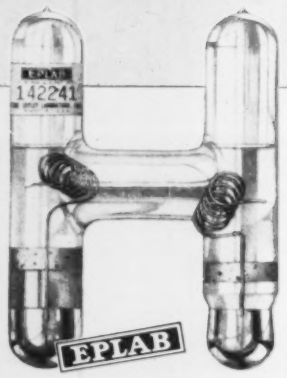

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NEWPORT RHODE ISLAND

The Electromagnetic Balance

(Continued from page 285)

electric balance is loaded by applying pressure to the Sylphon bellows. The current readings are directly proportional to a pressure applied to one of the bellows, or to the difference in the pressure in the right and left bellows if both are used. The notched beam is provided so that a given pressure may be balanced out with the weight, thus making the electrical readings indicate the difference from this given pressure. This is advantageous when it is desired to maintain a constant pressure, because readings may be amplified as much as desired to make small differences easily observed. Moreover, there is almost no lag in the readings even on the sensitive ranges, so that a change in pressure can be detected instantly and correction made before the error becomes objectionably large. The balance shown in Fig. 5 has a maximum range of 150-0-150 lbs./ft.^{2} and a minimum range of 1.5-0-1.5 lbs./ft.^{2}. These correspond to about 29-0-29 and 0.29-0-0.29 inches of water. On the fine range 0.001" of water gives about ½" pointer deflection. Even such small pressures are easily recorded on a standard 10-milliamp. recorder. Greater sensitivity can be provided but precautions must be taken to avoid the influence of outside air currents.

OTHER APPLICATIONS

Calibration of Electrical Instruments

When an accurate series of weights are applied to an electromagnetic balance, and careful readings of current are taken with an ordinary electrical measuring instrument, the readings will fall close to, but not exactly on the proper scale divisions. If several such instruments are connected in series, no two of them will show the same deviation throughout their scales. This suggests that the balance would make a convenient and accurate device for checking and calibrating instruments. Note that the possibility of error in the balance current is much less than that of the instrument, because the coil remains essentially stationary and fills the entire air gap, while on the other hand, the coil of an instrument not only rotates but moves in its jewel bearings, so that variations in flux distribution will cause slight changes in calibration. Moreover, there are no bearings or calibrated springs to influence the current from the electromagnetic balance. Springs are used in the suspension of the coil, but figures indicate that they contribute only about 0.01% of maximum coil pull, and this can be further reduced if desired.

Constant Current or Constant Voltage

If a fixed weight is applied to the coil of an electromagnetic balance, the output current will be held precisely constant and should afford an excellent laboratory reference. Note particularly that if resistance is added to the circuit, the current will remain the same until the voltage drop exceeds the capacity of the control circuit. As a result, instruments or other apparatus may be inserted or removed from the circuit without changing the current. If current requirements exceed the capacity of the vacuum tubes, a storage battery or other source may be used, leaving the vacuum tubes to supply the increments required to maintain the total constant. To control a larger power source, the current from the vacuum tubes may be passed through a separate winding on the field of a small generator. The balance coil must be inserted in the armature circuit, so that the vacuum tubes will vary the field flux in such a manner as will maintain constant current in the coil. If the coil is connected across the armature with a suitable resistance in series, the generator voltage will be held precisely constant within the limits of the vacuum-tube control. Thus current or voltage certainly can be held constant within 0.1%, and the ultimate precision greatly exceeds this figure. Under favorable conditions it should be possible to control generators up to about one kilowatt capacity in this manner.

Air Speed Control

The University of Washington Wind Tunnel has been equipped with an experimental automatic air speed control of this kind. The output current from the air-speed pressure balance is applied to a special relay which continually opens

and closes a circuit shorting out a portion of the field resistance of an 800-kw. generator, which in turn supplies the motors. The duration of the open-circuit and closed-circuit intervals is controlled by the current from the pressure balance, so that the average field current varies accordingly. To change the air speed it is necessary to accelerate the motors and the entire mass of air in the wind tunnel. There is a considerable lag between the instant that a change is made in the field current and the instant that a corresponding change in air speed is accomplished. Therefore, sudden changes in air speed produce over-control and hunting results. This is prevented by inserting an added control current which is proportional to the *rate of change* of output current from the pressure balance. Obviously, the air speed could not be held absolutely constant because of the unavoidable lag, but by applying the proper weight to the pressure balance, the average air speed could be held at any desired value, and a gradual oscillation would persist about this speed. Under normal conditions the change in air speed could be held within about $\pm 0.5\%$.

Miscellaneous Applications

The balance has demonstrated its ability to produce an electric current precisely proportional to an applied force. Also it has shown its ability to add or subtract, and to multiply or divide electric currents. Some interesting work has been done showing that a similar automatic balancing scheme can be used to accelerate a rotating mass in exact proportion with an applied force. The result is that the rotating speed of the rotor is a precise measure of the integral of the force over any given period of time, and the number of revolutions is a precise measure of the double integral over the same time. The details of this device have not been perfected to the point of obtaining good results, but the scheme is definitely workable and further progress merely awaits an urgent demand. Since all the operations mentioned can be performed on anything which can be converted into a mechanical force or an electric current, the possible applications cover an unusually wide field. In all its applications the Electromagnetic Balance offers the unusual advantage that its output energy is relatively large even though its input may be extremely small.

A General Consideration of Aircraft Instruments

(Continued from page 274)

forms of electric altimeters in which radio waves are reflected back to the plane. The latest reflected radio wave altimeter appears to be highly effective—but it is not yet in general use, and perhaps still another step is needed for complete practicability.

2. *An Absolute Ground Speed Indicator.*

It is sad to think that in a fog or darkness or over the sea, the navigator still has no direct indication of speed relative to the earth: only of speed relative to the air. There must be truth in the dictum that steady motion in a uniform field cannot be detected or measured. Every system hitherto suggested, such as the generation of electromotive force by cutting the earth's magnetic field, contains within itself a fundamental fallacy. The only system hitherto propounded which appears theoretically correct is that in which accelerations are integrated from the instant of take-off and the mechanism involved is of insurmountable complexity.

3. *Problems in Air-Speed Indication.*

We have just observed that indication of speed relative to the air is available. But the accuracy of such indication is far from assured and some very pretty problems remain for solution. Where should the Pitot tube be placed so as to be immune to position error? In normal flight the position error can be almost eliminated by locating the Pitot ahead of the leading edge, but exploration and calibration is always needed. When the landing flap of the modern airplane is depressed the position error becomes important because the entire system of flow around the wing is modified. Accuracy of the Pitot in a side wind is doubtful. To prevent icing-up of the tube, an almost prohibitive amount

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Shown here is a view of one section of the automatic screw machine department in the modern Triplett plant where essential parts—some as minute as the smallest used in watches—are turned out 24 hours a day. More and more, Triplett has turned to wholly automatic fabrication of materials to speed up production and to eliminate any possibility of human error. To assure parts best suited for Triplett needs, company engineers have pioneered in the design and manufacture of countless fabricated materials including switches, bar knobs, resistors, jacks, special adapters, etc.—a complete service intended to give each user the fullest measure of satisfaction.

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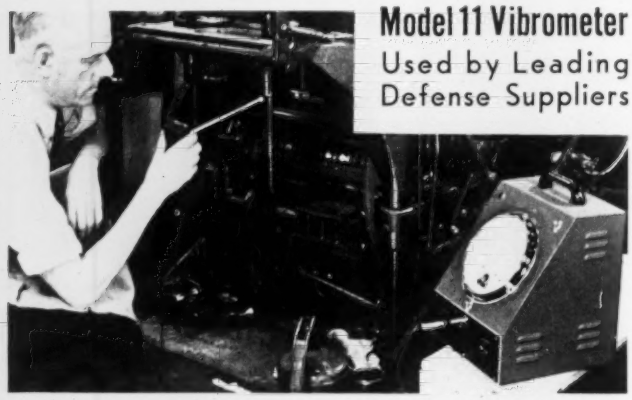

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In this time of national emergency Alnor pyrometers quite naturally go first to jobs of defense. However, customers unable to furnish priority certificates will be taken care of to the best of our ability. Quite possibly there is a problem confronting you that our engineers can help solve—with or without need of new equipment. We will consider it a privilege to help work out your pyrometric problems, even though no new equipment is involved.

Illinois Testing Laboratories Inc.
142 W. Hubbard St. Chicago, Ill.

of electrical energy has to be supplied. For some aspect of technical aeronautics, it is desirable to know the air speed exactly at the instant of take-off or landing; the air speed indicator fails dismally at such times because of lag and because of ground effect.

4. *Instruments for Blind Flying.*

The radio beacon is a great help to blind flying. But it sometimes is desirable to be able to fly blind without radio aid. We need therefore a compass immune to all turning errors, gyroscopic inclinometers which give absolutely true indications relative to the vertical, and absolutely correct turn indicators. The present blind flying instrumentation is splendid but there is still room for improvement.

5. *Flutter Investigation.*

The greater the speed of the airplane the more it is likely to encounter flutter, which is an aerodynamically induced and perpetuated oscillation, quite distinct from vibration. Pick-ups, amplifiers, and oscillographs enable periods and intensities of flutter to be studied but the instrumentation is complex and more of the laboratory than of the field engineering type. An opportunity exists in the simplification of the apparatus, which belongs to experimental engineering rather than to natural flying operations.

6. *Instruments for Stress Measurement.*

The structural analysis of the modern airplane is a complex matter, and direct measurements of stress distribution in flight are desirable. Here again instrumentation of the field engineering type would be welcome.

7. *Instruments for Private Flying.*

Aircraft instruments are a miracle of applied science. They are also expensive. If an air flivver were really well equipped with the instruments now available, the cost of the instruments would far exceed the cost of the plane. There is room for the enterprising manufacturer who will give the private flier a dashboard not much more expensive than that of the automobile, yet more accurate.

Even these few examples show what splendid opportunities for development exist in this field.

Calibrating Vibrometers

(Continued from page 281)

Fig. 7 shows the open-circuit voltage of two different makes of torsional pick-up units. Unit *A* shows a linear output up to about 150 c.p.s. Above this point, the output begins to fall off until at 300 c.p.s. it is about 25% below continued linear response. Unit *B* shows a linear response over the range to 300 c.p.s. Unit *B* also shows a higher output voltage for the same displacement. Similar calibration curves are necessary for linear units.

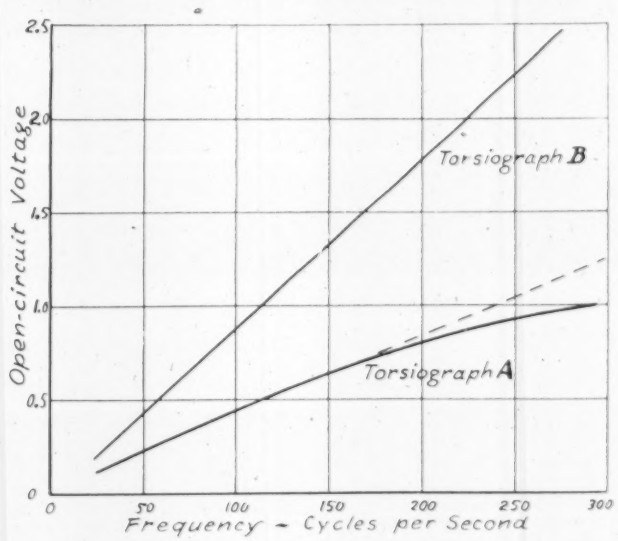

Fig. 7. Comparative characteristics of two torsional pick-ups. Torsional amplitude ±0.5°.

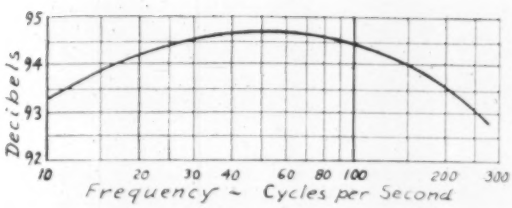

Fig. 8. Frequency response of a torsional pick-up measured on a sound frequency analyzer. Torsional amplitude ±0.5°.

Fig. 8 shows the overall frequency response of a torsional unit in combination with an electric analyzer, which is electrically weighed to indicate displacement. This unit must employ a correction curve to compensate for the lower indications at the high and low frequencies.

Test data, obtained beyond the calibrated range of an instrument, can never be considered reliable. Measurements taken by instruments are never more accurate than the calibration of those instruments; consequently an increase in the accuracy of calibration means a better knowledge of the limitations of the instrument and a better evaluation of test results.

Instrument Flight Training

(Continued from page 290)

might throw the pilot miles off course, depending on the strength and direction of the wind, if used on one of the other two patterns. A range pattern is the pattern created by the direction of four radio beams being transmitted from a range station. The three types are:

(1) The square or right-angle, in which the four beam signals go out from the station at right angles;

(2) The squeeze pattern, in which the four beams roughly form the shape of an open scissors, two sectors being squeezed and two open or more than 90 degrees;

(3) The crow-foot pattern, where the signals are directed away from the station at different angles in which you find sectors of more than 90 degrees, 90 degrees, and less than 90 degrees.

Next comes a comprehensive course in use of the loop antenna to obtain location fixes or, in other words, to establish the plane's position. The loop is of particular value because wind drift will not affect this type of orientation nearly as much as the so-called different systems of orientation. Winds as high as 90 m.p.h. can be simulated in the trainer. The loop course in the Link is divided into several general classifications. The student is taught how to "home" to his destination; how to orient himself and estimate his distance from any established point on his route; how to follow his course to a given range station; and how to set his directional gyro without help of his magnetic compass by obtaining bearings on two separate radio stations to determine direction of flight.

With the Link trainer course behind him, the first officer is assigned to a Stinson instructor for actual flight work. The Stinsons are four-place ships, equipped with 350-hp. Wright engines, and were built to TWA specifications. Instrument panels are virtually duplicates of those found on our transports, and the ships thus serve the same purpose in instruction at less expense. The crew usually consists of instructor and two students. One student will observe, while the other flies and will profit by his mistakes.

The stages of training in the Stinson consist of seven hours of basic familiarization flying, orientation problems identical with those performed in Link trainer, problems in loop antenna use, practice flying on radio legs with loop in rain static or loud position as opposed to silent or null position, aural orientation with hand-operated loop and with automatic direction-finder loop, aural homing to station with and without wind, a distance estimate through use of direction-finder, setting directional gyro without use of magnetic compass by loop bearings on two radio stations, triangulation—plot bearing from two or three stations with loop, orientation on commercial broadcast stations, four-point bearing to get distance from station, visual instru-

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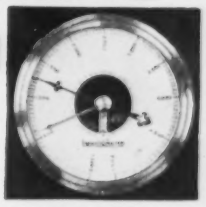

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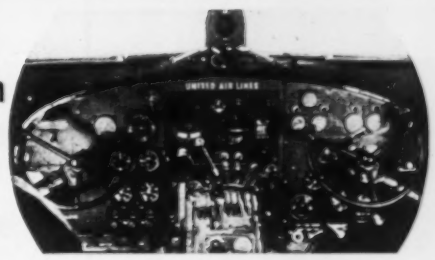

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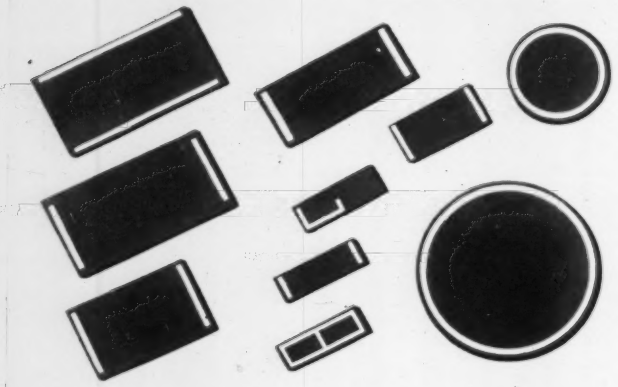

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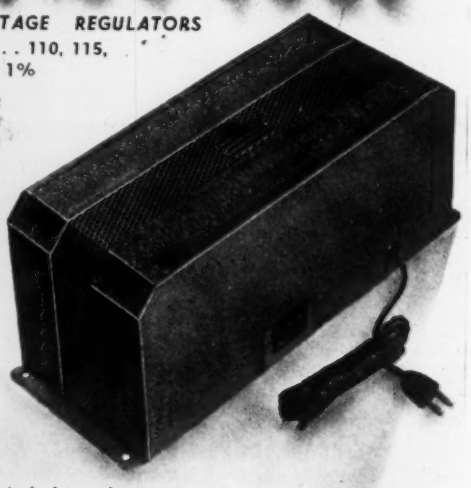

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Temperature Measurement Course

UNIVERSITY OF PITTSBURGH

To the Editor of *Instruments*

You are doubtless aware of the Engineering, Science and Management Defense Training courses being offered by Carnegie Tech, Penn State College and the University of Pittsburgh. As of possible interest, however, because of your interest in industrial temperature measurements, may I call attention to the course entitled "Industrial Temperature Measurements" for which I am responsible.

The description of this course follows: Temperature scales and Standards; Liquid-in-glass thermometry; Bimetal thermometry; Resistance thermometry; Thermoelectric thermometry; Representation of results by graphs and equations; Pressure-spring thermometry; Optical pyrometry; Total radiation pyrometry; Color match pyrometry; Temperature control; Temperature recording; Production of high temperatures; Repair and servicing of apparatus.

As for all defense courses there is no charge for tuition though students taking the course must pay for books, notes, apparatus, etc., which they use or break. Registration for this course occurs Oct. 8, 9, 10 and 11, afternoons and evenings and Saturday morning, Oct. 11, at the Men's Gymnasium, Carnegie Institute of Technology. The lecture in the course meets Monday, 6:30-10:00 P.M. and the laboratory one other night a week.

October 6, 1941 A. G. WORTHING.

LAST-MINUTE BULLETIN—At the moment of going to press we learn that the number of registrants does not seem to warrant starting the course now (it probably will start in early February). In our opinion, the reason is simply that the notices were mailed out too late. We urge all readers in the Pittsburgh district to bring this valuable course to the attention of all persons whose work is related to temperature processes (metallurgical, ceramic and other industries) and to important temperature measurements (research, etc.). —ED.

Statement of the Ownership, Management, Circulation, etc., Required by the Acts of Congress of August 24, 1912 and March 3, 1933, of *Instruments* published monthly at Pittsburgh, Pennsylvania, for October 1st, 1941.

State of Pennsylvania, County of Allegheny, (ss).

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Richard Rimbach, who, having been duly sworn according to law, deposes and says that he is the Publisher of *Instruments* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation) etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business manager are:

Publisher, Richard Rimbach, Pittsburgh, Pa. Editor, M. F. Behar, Pittsburgh, Pa. Managing Editor, Richard Rimbach, Pittsburgh, Pa. Business Manager, Richard Rimbach, Pittsburgh, Pa.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock.)

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[SEAL] Edward M. Seibert, Jr.

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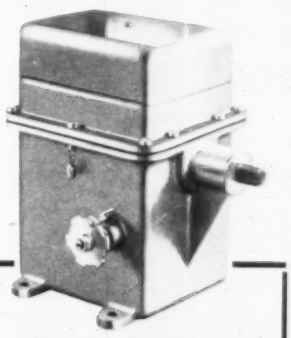

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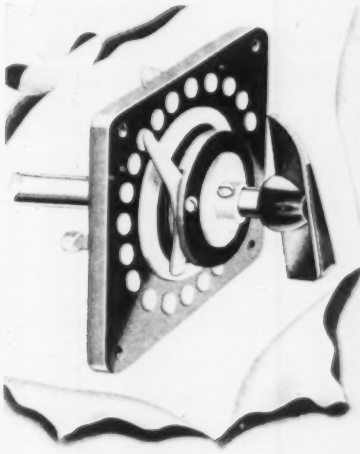

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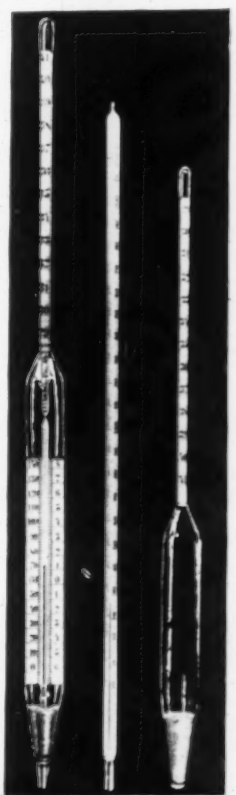

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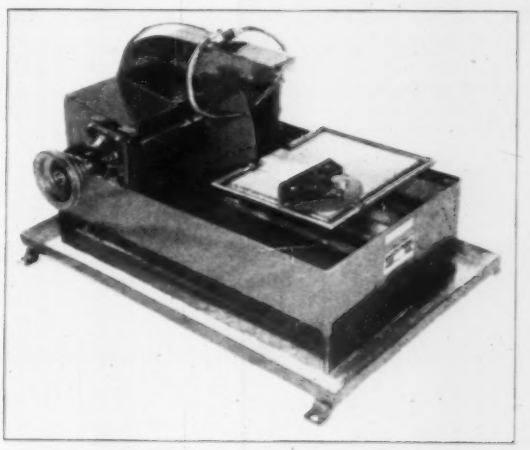

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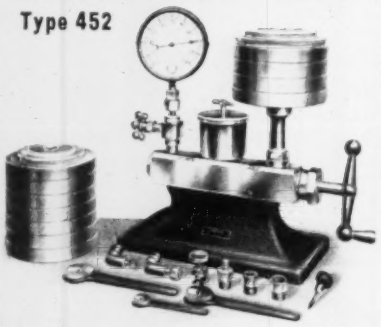

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THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

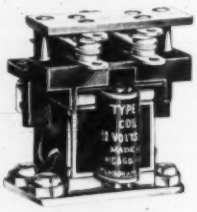
When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Vibrometer

Announcement is made of an improved model of indicating vibrometer (see *Instruments*, Oct. 1940, page 292; July 1941, page 194). New "Model 11-A" reads not only displacement but acceleration and velocity values.—*Televiso Products, 2400 N. Sheffield Blvd., Chicago, Ill.*

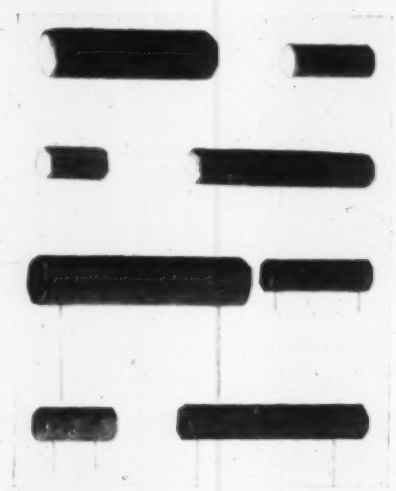
Aircraft Type Relay

As a part of its program of new products for National Defense, manufacturers announces new Type "J" Relay: small, light and said to be of exceptionally rugged construction. Suitable for use at high altitudes, it is designed to withstand aircraft vibration and "high" acceleration. That it will operate satisfactorily under "high" humidity conditions is another claim. Type "J" relay has two poles, and self-cleaning contacts. It is available in quantity. Overall dimensions 1⅞" high, 9/16" long, and 1⅝" wide. Coils are designed for operation on direct current and are particularly suitable for aircraft voltages.—*G M Laboratories, Inc., 1731 Belmont Ave., Chicago, Ill.*



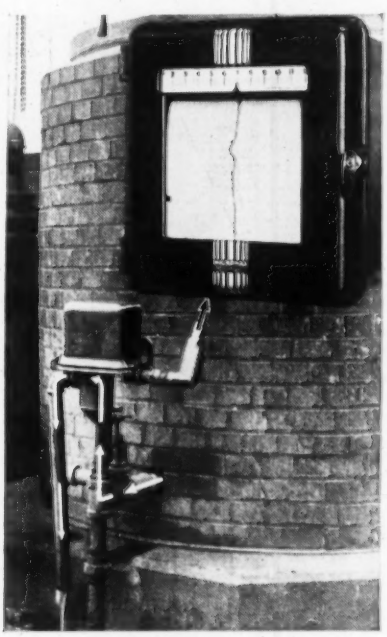
Resistors with Negative Temperature Coefficient

A line of negative temperature coefficient resistors, with metal coated ends for making electrical connections, is announced. It simplifies design problems by permitting the use of cartridge or clip method of mounting. Chief characteristic of Keystone resistors is decrease in electrical resistance with an increase in temperature. This property makes the material useful where it is desired to reduce or eliminate initial current surges, to secure a time delay or "gradual building-up" of the current through a piece of equipment, to provide temperature compensation in apparatus or equipment which exhibit rising resistance with increase in temperature, etc. At present, Keystone negative temperature coefficient resistors are available in four standard sizes, shown (actual sizes) in the illustration: 5/32" × 3/8", 5/32" × 1/2", 5/32" × 1", and 1/4" × 1". These have maximum wattage ratings ranging from 0.75 to 3.0 watts.—*Keystone Carbon Co., 1935 State St., Saint Marys, Pa.*



Dehydrator Water pH Indicator-Recorder

Continuous indications and records of the pH of dehydrator water are provided by new "42101-C6" (illustrated) or "32101-C6" equipments—the latter comprising maker's round-chart "Micromax" indicator-recorder with large bold pointer readable from a greater distance but with one-third the chart scale width of the strip-chart "Micromax" indicator-recorder. Both equipments employ the maker's glass electrode assembly through which a continuous sample of the dehydrator water flows without interruption. This electrode assembly includes an electrical temperature compensator and has a thoroughly weather-proof housing. Installation of electrode assembly and of either model of instrument does not involve altering existing refinery equipment, can be made by plant maintenance men.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*



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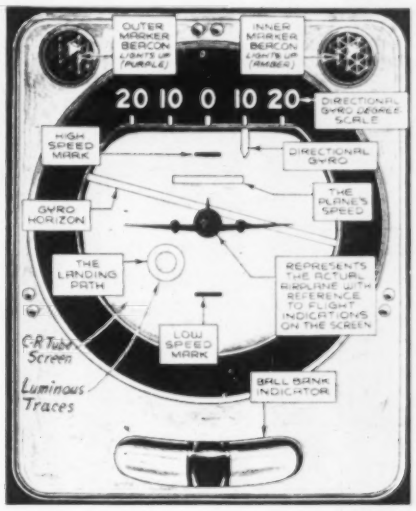
New combination device known as the "Flightray" is announced after more than a year of actual service use. It is designed to simplify the work of the pilot of large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THE PLANE'S SPEED
THE LANDING PATH
REPRESENTS THE ACTUAL AIRPLANE WITH REFERENCE TO FLIGHT INDICATIONS ON THE SCREEN
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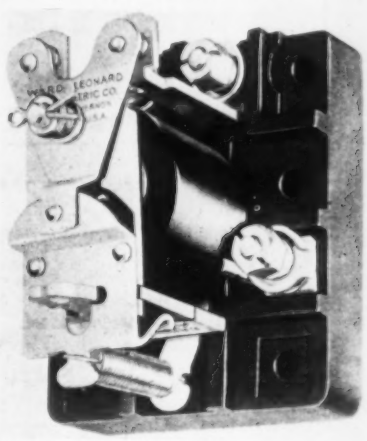
aircraft by bringing the indications of a number of instruments to the face of a single dial. It consists essentially of a cathode-ray tube, on the screen of which are projected luminous traces representing all necessary flight information, produced in rapid rotation so that to the eye they appear to be simultaneous. An electromagnetic pick-up is associated with each instrument so that the Flightray gives in one reading the immediate flight information from the following instruments: gyro-horizon, directional gyro, air speed indicator, radio compass and radio landing beam. The Flightray is especially applicable to instrument flying. Its most important function in this connection is showing the location of the airplane with respect to the landing path beam.—*Sperry Gyroscope Co., Manhattan Bridge Plaza, Brooklyn, N. Y.*

Midget Magnetic Relays

Recently improved in construction details and materials, "Bulletin 106" relays are now furnished with a molded Bakelite base providing lighter weight, greater protection



against absorption of moisture, higher insulating qualities, and increased mechanical strength. All double-pole relays now have rubber-insulated lead wires. On d-p.d-t. relays, contacts carried by the Bakelite arm are now secured by a spun over riveting operation that requires no facing and thereby eliminating open end grain contact.—*Ward Leonard Electric Co., 31 South St., Mount Vernon, N. Y.*

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Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

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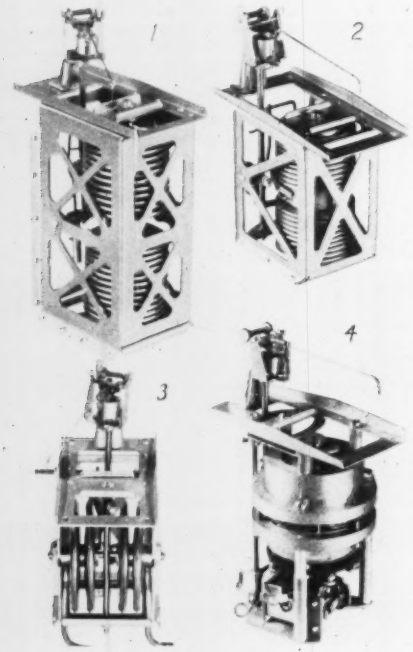
1041 Ivanhoe Rd., Cleveland, Ohio

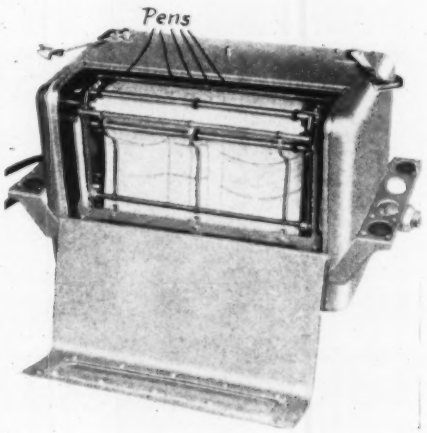
Flight Data Recorders

[Ed. Note—For description of original "Flight Analyzer," with 3" × 5" card charts, see *Instruments*, July 1937, page 173; for special multi-pen models see *Instruments*, Feb. 1940, page 51.]

New Friez Flight Analyzers have been especially designed for installation into larger types of commercial transport and military and naval aircraft to provide automatic, continuous records of various flight conditions such as altitude, air speed, and vertical acceleration, or of the power-plant functions such as r.p.m., oil temperature and pressure, and manifold pressure. Recorders may be placed in any suitable location in the aircraft, will normally require no special service between plane and engine overhauls,



when all other instruments are checked. There are two standard types, No. 643 record Air Speed, Vertical Acceleration, Altitude, and two operations. These latter are used for recording the use of such equipment as the gyro pilot, radio, instrument warnings, etc. It is possible to include two additional operations or "off-on" pens, or all such pens may be omitted if desired. No. 644 incorporates four Pioneer Autosyn-actuated pens, thus making available records of any measurements transmitted by Autosyn transmitters located at suitable points and actuated by primary elements for measuring temperatures, pressures, speeds, etc. All portions of Analyzer are made easily accessible. Entire housing or outside case may be removed with four screws, exposing complete chassis carrying the individual units. Complete clock drive mechanism is exchanged by the removal of four screws. Each individual recording unit may be quickly lifted from Analyzer, again with only four screws, and each unit remains a complete entity, recalibration not being made necessary by removal from the recorder. Taking out one unit does not disturb the others. Four types of individual recording units are illustrated. The Altitude Unit (1) employs a novel system of opposed diaphragms, one cell being evacuated, the other connected to the static line. Temperature correction is assured across standard range of 31" to 11" mercury (0 to 25,000 feet). Connection with the static line may be made to standard head used for present indicating instruments. The Vertical Acceleration Unit (2) is a new liquid-damped opposed-sylphon type of special Friez design. A weight is suspended between the vertically stacked Sylphons which serve as springs. Liquid in the closed system is pumped through a hole in the weight, the size of this hole determining the degree of damping. Operation of this new type unit is extremely flexible in possible special applications for horizontal as well as vertical acceleration recording. The Air Speed Unit (3) employs novel system of opposed diaphragms. One cell is connected to the Pitot line, the other to the static line. Temperature correction is unusually satisfactory throughout the standard range (up to 2[illegible] m.p.h.) The Autosyn Unit (4) includes standard Pioneer Autosyn motor for connection to any Autosyn transmitter with suitable gear ratios provided to cover the various ranges. A special heart cam is built into the unit to avoid complications in event of shifting of positions of transmitters during power-off periods. A standard multiple plug jack connector is provided for all electrical connections required either for Autosyn units or operations pens. The Operation Unit (not illustrated) is a special solenoid (wound as standard for 12 volts d.c. but other windings available) connecting in electrical parallel with existing or special switches, thus providing records of the operation of such functions as radio transmitter, gyro pilot, de-icers, warning signals on indicating instruments, etc. The Clock Mechanism is a special Remontoire (hand-



wound) of novel Friez design, said to insure continuous, trouble-free service even under extremely adverse conditions. At standard chart speed of 2.4" per hour, clock and chart drive mechanism will run appreciably over 24 hours without rewinding. Means are provided for easily starting and stopping the clock and danger of overwinding is eliminated. The chronometer releases periodically an escapement which permits a strong main spring to drive the chart mechanism and simultaneously rewind the separate smaller chronometer spring. The pens are of capillary type, each provided with its individual ink reservoir with adequate capacity to give a continuous record throughout an entire chart roll. A simple zero setting adjustment is provided on each pen. The pens and ink reservoirs may be quickly and easily removed for cleaning without disturbing the sensitive portion of the recording units. Standard chart roll is long enough to provide continuous records of approx. 200 hours (at standard speed); renewal is accomplished more easily than the film on a camera. Total weight of the No. 643 instrument is approx. 8 lbs.; that of the No. 644 recorder slightly higher. Overall dimensions for the complete No. 643 are approx. 8" high by 6" deep by 16" wide (including brackets carrying Lord type mount). No. 644 instrument has same height and depth but is 19" wide.—*Julien P. Friez & Sons, Baltimore St. & Central Ave., Baltimore, Md.*

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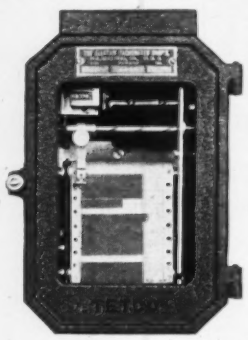

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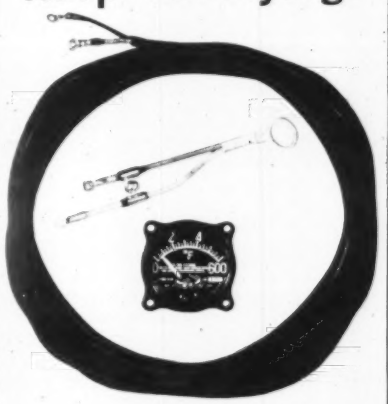

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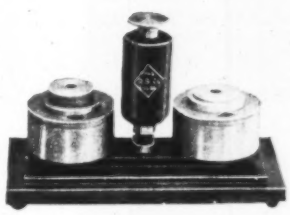

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For measuring gas pressures by actual dead weight. This gauge can be put on a line similarly to test gauge.

R. S. PORTABLE GAUGE TESTER

A Dead Weight Tester with easy portability for testing gauges.

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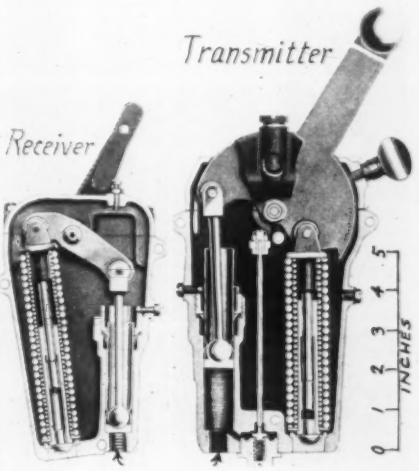
Hydraulic Transmission

New "Exactor Control" consists of two elements: the transmitter fitted with a hand-manipulated lever, and the receiver with a lever which follows the first accurately with no loss of motion. The only connection is a single $\frac{3}{16}$" aluminum tube (fitting where arrows have been drawn on illustration) which can be bent to pass intervening obstructions. Furthermore, short lengths of flexible connecting tube may be used if either the transmitter or receiver is required to move. The cylinders of transmitter and receiver are each fitted with a trunk type piston, fluid tightness being insured by a specially packed gland. Cylinders and connecting pipe are completely filled with a liquid of low freezing point and, since both cylinders are of equal diameter, a downward movement of one piston must result in a similar upward movement of the other. Pistons are connected by rod and radial crank arm to their respective shafts, so that longitudinal movement is converted into rotary movement. Fluid in the system is kept under pressure at all times by means of opposing springs acting on the two pistons.



Angularities designed into the mechanism counteract the varying forces of the expanding and contracting springs so as to maintain constant piston pressures at any point in the stroke. Preloading by spring at each end prevents mechanical lost motion or backlash and, since the fluid is practically incompressible there is an overall "rigidity" whereby, it is said, the slightest movement of transmitter is duplicated at receiver. System self-synchronizing characteristic is accomplished by having lower end of transmitter cylinder communicating with a reservoir through a spring-loaded valve. In normal operation this valve is closed, but when the operating lever is moved to the end of its stroke (in aircraft, the "full throttle" position), the final few degrees operates the valve mechanism and opens the valve against the action of the spring; the system is then open to the reservoir and pressure is instantly released. Any variation in volume is thus automatically compensated for, a deficiency being made up from the reservoir or an excess being driven out by the receiver piston which, on release of the pressure, is forced to the bottom of its stroke under the action of its spring. The initial backward movement of a few degrees of the transmitter allows the valve to close and any further movement will be exactly reproduced by an equal movement at the receiver. Similarly, release of pressure in system, in event of pipeline fracture, causes receiver piston to be forced to end of its stroke under action of its spring; any failure will thus result in the control moving to a predetermined position. For most applications, various blends of kerosene and readily-available motor oils serve as refilling—no special fluid being required.—*Sperry Products, Inc., 1505 Willow Ave., Hoboken, N. J.*

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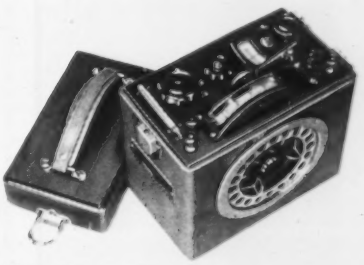

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20" to 150" of Water

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Standard Differential Range
1" to 8" of Water

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RING · BALANCE INSTRUMENT CO.
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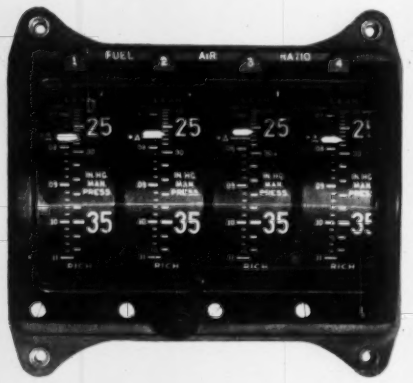
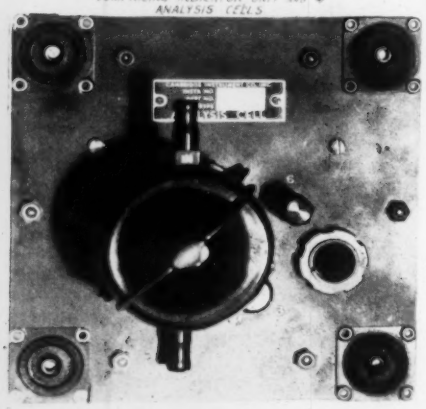
Exhaust Analyzers Indicate Fuel-air Ratios

Continuous measurement of engine fuel-air ratio is effected by continuous automatic analysis of exhaust gases from each engine (thermal-conductivity method), and indications are brought to small panel-board instruments, in new "Aero" Models of Cambridge Exhaust Gas Testers. Announcement states that manufacturer was first to bring out accurate gasoline-engine fuel-air ratio indicator: in 1924, "before the market was ready for it," and that recent refinements minimize weight of components of system and at same time result in heretofore-unrealized combination of accuracy and reliability under service conditions. Announcement specifically lists error sources said to be overlooked by majority of workers, and describes corrective means, among them the following: *Variation in temperature of exhaust gas or surrounding air.* The four platinum spirals composing the four arms of the bridge must be individually insensitive to all extreme temperature changes. They are accordingly located in chambers drilled in one metal block so that no great temperature inequalities can exist. This method of spiral mounting takes care of inequalities of temperature as between spirals, but unless the spirals themselves are carefully matched in their temperature-resistance characteristics, changes in base temperature of the whole group will again affect accuracy. *Variations in gas velocity.* Exhaust gas testers in which the exhaust gas sample is actually caused to flow through the chambers containing the measuring spirals are particularly susceptible to this error: changes in engine speed readily produce more change in bridge balance than do changes in gas composition which instrument is intended to measure. In such designs it usually is necessary for the operator to adjust a flow valve with reference to a manometer, and to correct this adjustment for every change of engine speed. In the Cambridge Analysis Cell the only access to the chambers containing the measuring spirals is by means of small diffusion holes



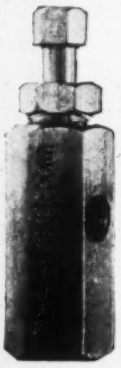
CAMBRIDGE 4 ENGINE AERO MIXTURE INDICATOR COMPRISING INDICATOR UNIT AND 4 ANALYSIS CELLS



opening into a larger passage which, in turn, is open at its outer end to the exhaust gas. Diffusion takes place through the holes, without any actual flow through the spiral chambers. Consequently, accuracy of instrument is independent of engine speed. Models are available for single-, twin- and four-engine installations. — *Cambridge Instrument Co., Grand Central Terminal, New York City.*

STOP WORRYING ABOUT GAUGE DAMPENING PROBLEMS

THE MARTIN-DECKER UTILITY MODEL PULSATION DAMPENER *is smoothing out gauge readings on thousands of installations all over the world!*



INSURES ACCURATE READINGS

Gauge hand movements protected with this Dampener are unaffected by pulsating pressures. Chart records are easier to read, more valuable. Unit can be used on air, gas, oil, water, steam, gasoline pressure lines, etc. Dampens out slow or rapid pulsations with smallest possible amount of drag or time lag.

ADAPTABLE—installations can be made in any position desired without affecting efficiency.

ECONOMICAL—quickly pays for itself by protecting gauges and recorders from damaging pressure surges.

TWO MODELS:

Regular Brass Body—Stainless Steel Stem — Vacuum to 300 pounds

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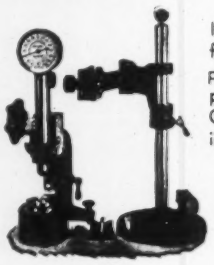

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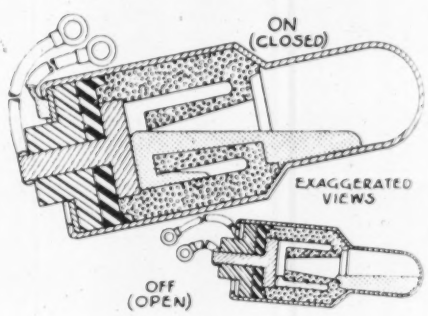
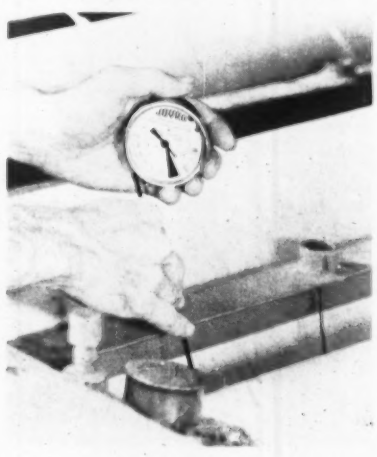
Double-flow Mercury Switch

In new anti-vibration model of Durakool Mercury Switch, two tails of mercury pulling in opposite directions, over a ceramic barrier until severed, prevent double contacting where vibrations exist. When closing, the two approaching bodies of mercury pile up a double-thick electrical conductor. Double flow is said to operate either as a slow rolling motion or equally well on a high-speed mechanical snap action. Switches in unbreakable metal of 10, 20, 35 and 60 amps. are available. Priorities required.— *Durakool, Inc., 1029 N. Main St., Elkhart, Ind.*



Ironer Pressure Indicator

New "Joyro Pressure Indicator" is said to be the first gage ever developed to determine flatwork ironer roll pressures accurately and thus permit scientific settings for maximum padding life and high quality production. It consists of a flat watch-spring strip connected to a tension gage. In use, instrument is held in one hand above and slightly to the rear of roll to be tested, while other hand guides the spring strip under the roll, as it turns, between it and the chest. Tension is shown on the dial. To facilitate proper adjustment, a segment is marked off on the dial to show correct operating range. Heretofore, it is said, a sheet of paper held between the fingers, was the only method of testing. Joyro Pressure Indicator determinations show general maladjustments, including warped chests, which directly affect operation costs, volume of production and finished quality. — *George Rosales Co., 784 Stanford Ave., Los Angeles, Calif.*



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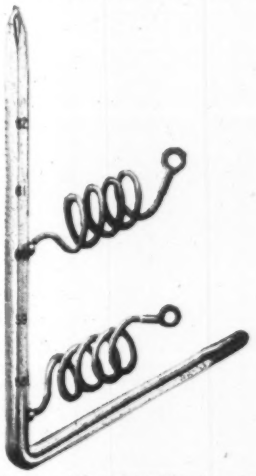

● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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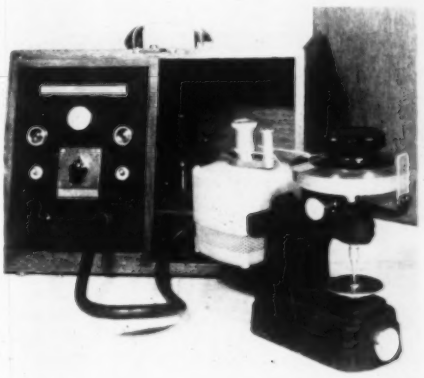
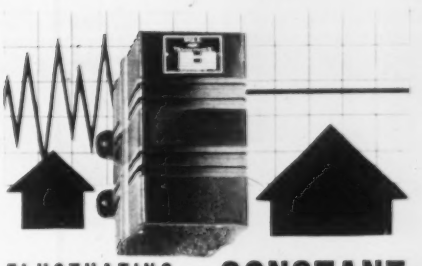
Electronic Micrometer Diaphragm Tester

In testing diaphragms as used in aircraft instruments and thermostatic controls, it usually is desired to measure the performance of the completed diaphragm to determine deflection rate and drift. It is necessary to measure deflection rate in order to determine whether responses to changes in temperature or pressure are of proper magnitude; it is necessary to measure drift to make sure that the diaphragm-controlled device will maintain its initial calibration. In both cases the measuring method or instrument must not in itself influence the diaphragm performance. This prime requirement is met in new Carson Electronic Diaphragm Tester through the use of a motor-driven micrometer head controlled by an electronic circuit operated by physical contact between the micrometer tip and the surface of the diaphragm being tested. A large-diameter dial mounted on the micrometer head is driven through a small adjustable-tension belt from a pulley on a small reversing shaded-pole gear motor. Motor is controlled by the electronic circuit in such a way that before contact is established at micrometer tip, micrometer is rotated by motor to bring tip against diaphragm. Upon first instant of metal-to-metal contact between micrometer tip and diaphragm, and before any pressure is exerted by micrometer tip, motor is reversed by electronic detector unit. As soon as contact is broken, motor again rotates dial into contact. Thus a "hunting" action is obtained and, by adjusting motor speed, the range of hunting-action can be reduced to less than 10 millionths of an inch. Micrometer then will instantly respond to any change in diaphragm position either upward or downward, automatically bringing dial to proper reading point. Since the operation of the diaphragm tester is entirely automatic, no human element is involved in measuring the diaphragm response. Since no pressure is exerted by the instrument against the diaphragm, the readings taken are unaffected by the measuring method. The complete measuring head can be enclosed within a bell jar 10" in diameter for testing sealed diaphragm units by changing the external pressure. The micrometer head has a range of ⅞" over which the maximum deviation is not more than 30 millionths. The instrument will repeat well within 10 millionths and is sensitive to changes as small as 5 millionths. Dial shown in illustration has 500 divisions, each division 0.00005; each thousandth numbered. All controls for the instrument are contained on the cabinet panel into which the electrical connections from the micrometer are plugged. Instrument is supplied as shown with a mahogany carrying case containing electronic unit behind panel and having a compartment for storing instrument when not in use. Although this is manufacturer's initial announcement, instrument is already in successful use in four aviation instrument plants, where it has largely supplanted optical fine-measurement equipment.—*Instrument Specialties Co., Inc., Little Falls, N. J.*





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Whether it's 1 VA for an instrument or 10 KVA for a Production line—here's constant, stable voltage for you at all times, even though the line voltage varies *as much as thirty percent.*

They are fully automatic and instantaneous in operation—have no moving parts—require no maintenance—and are self-protecting against short circuit.

You can build a SOLA CONSTANT VOLTAGE TRANSFORMER into your product, or incorporate it in your production line or laboratory and know that every test will be made under identical line conditions.

Compact—economical. Standard designs are available, or units can be built to your special specifications. *Ask for* **Bulletin GCV-74**

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TRANSFORMERS

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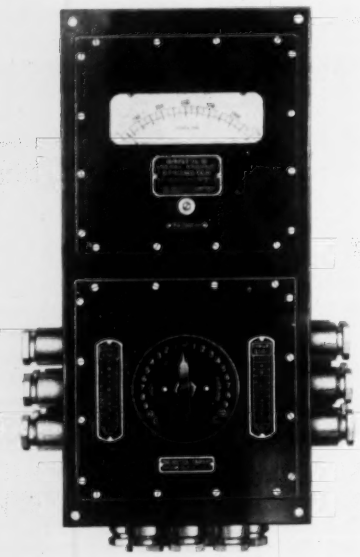
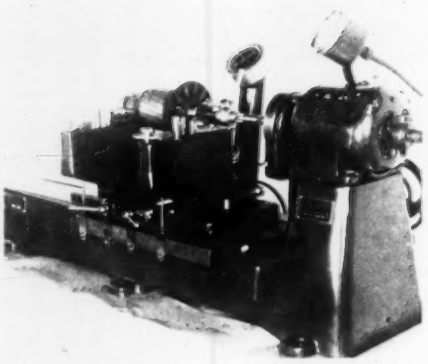
Diesel Engine Pyrometers

Several new Diesel engine pyrometers designed especially for seacraft are announced. Indicators are high-resistance millivoltmeter movements with automatic reference-junction compensation, are highly damped to withstand excessive vibration, are housed in drip-proof welded steel cases. Thermocouple selector switches are of rotary type with double contacts of laminated phosphor-bronze. All parts are designed to meet latest Naval specifications.—*The Bristol Company, Waterbury, Conn.*



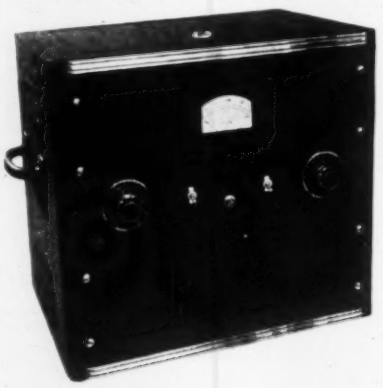
Dynamic Balancing Machine

New "NE-2 Globe Supersensitive Dynamic Balancing Machine" determines the amount and location of the corrections required in overcoming the unbalance in rotating parts weighing from 5 to 50 lbs. "Micro-Indicator" dial on top front of each balancing head indicates and records amount of correction required in its respective correction plane. Angular location is indicated and recorded by the "Neon-Lite" head. Approx. 30 seconds is required by the average operator in determining the condition of unbalance and required corrections on a typical rotating piece. Correction required for each end can be read directly, without cross transfer. This is made possible by the "Equipoise" feature which locks out the unbalance in one place while reading that in the other. Then, without stopping machine, locking point can be shifted to the first plane while reading the unbalance in the second. Heads are adjustable along the keyways to accommodate lengths of 5" to 26" between bearings. Corresponding adjustment is available along the "Equipoise" bar, obviating necessity of calibration in locking out proper correction plane in any new piece. Adjustable resonance is made possible by external snubber springs. Variable-speed drive is provided: 0 to 5000 rpm. in an infinite number of stops. Smooth acceleration to any pre-determined speed is thus made possible. —*Globe Tool & Engineering Co., Dayton, Ohio.*



A-c. Voltage Regulator

Illustrated is one unit in new "SECO" line of automatic voltage regulators. This regulator maintains constant output voltage with variations in input voltage or load current. It consists of a Thyratron circuit controlling a motor-driven variable voltage auto-transformer. These regulators are available for use on 115-, 230- or 440-volt circuits in capacities up to 75 kva. Output voltage and sensitivity are both adjustable over a wide range by means of knobs on front panel. Regulator is said to have the high efficiency and low exciting current characteristics inherent with the variable voltage auto-transformer. Response is rapid, full-range travel time of 6 seconds. Operation of regulator is not affected by changes in power factor of load. Also the regulator itself does not affect the power factor of the system.—*Superior Electric Co., 132 Harrison St., Bristol, Conn.*



Limit Bridge for Production Testing

New "Model 618" is a highly specialized Limit Bridge for rapid and accurate testing of multi-tapped resistance with varying unit values. It has binding posts for connecting a galvanometer and battery. Special mercury wells provide a method for attaching a multi-tap resistance resistor. A special Shallcross rotary switch selects the unit of the multi-tap to be tested and at the same time places the proper standard in circuit. A suitable key switch tests the tap for high and low tolerance. On a resistor having 18 taps, with this new equipment a thorough and accurate test has been made in about 1 minute. An ordinary Wheatstone Bridge required at least 30 minutes for the same tests.—*Shallcross Mfg. Co., Collingdale, Pa.*

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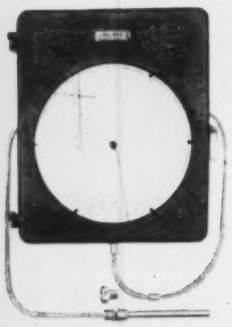

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MANUFACTURERS' NEW LITERATURE

In this department we report ALL pieces of NEW literature pertaining to Instrumentation, received from the manufacturers. Readers may secure without cost (unless noted) any or all items reported here, by filling out and mailing the card.

I-334 **Film and Plate Processing Equipment.** Bulletin, 8½" × 11", 4 pages, describes and illustrates equipment for spectro analysis, metallography and x-ray-film developing machine, plate developing machine, film washer, film dryer, plate washer and plate dryer. Harry W. Dietert Co., 9330 Roselawn, Detroit, Mich.

I-335 **Quartz Crystals.** Catalog G-12, 8½" × 11", 16 pages, covers general communication frequency crystal units for all services other than amateur, includes price list. Bliley Electric Co., Erie, Pa.

I-336 **Amplifiers.** Catalog 600-F, 8½" × 11", 16 pages, covers 8, 10, 14, 30 and 55 watt amplifiers, studio, phono, 18 and 28 watt mobile, battery, 25 watt rack, booster and pre-amplifiers with prices listed for each. Thordarson Electric & Mfg. Co., 500 West Huron St., Chicago, Ill.

I-337 **Continuous Gaging.** Bulletin, 8½" × 11", 6 pages, describes and illustrates Schuster calendar gage, operating on 110 volts; 50-60 cycles, for gaging sheeted stock, consists of three elements —setting devices, magnet carriages and indicating meter. The Magnetic Gauge Co., 60 East Bartges St., Akron, Ohio.

I-338 **Dynamometers, Special Scales and Test Apparatus.** Catalog No. 30, 8½" × 11", 20 pages, covers shunt type, traction, circular with free pointers, straight type with free pointers, special push-pull types and circular spring dynamometers with fixed pointers, special scales, test apparatus and special springs. John Chatillon & Sons, 85-93 Cliff St., New York City.

I-339 **Miniature Panel Instruments.** Catalog Section 43-330, 8⅜" × 10⅞", 12 pages, describes and illustrates miniature a-c. and d-c. voltmeters and ammeters in the two inch classification for general use. Permanent white dials, interchangeability of parts and high overload capacity are among features discussed. Dept. 7-N-20, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

I-340 **"C-D Capacitor."** Vol. 5, No. 7, 14 pages, contains Part II of "Biasing Methods" and article entitled "Personal Power Supplies"—three methods of operating miniature receivers from the house current. Cornell-Dubilier Electric Corp., New Bedford, Mass.

I-341 **Electric Pressure Gages.** Bulletin GEA-3477, 8" × 10½", 2 pages, describes and illustrates gages for the measurement of pressures of either liquids or gases, work on same principle as for standard electric gage. Can be used to investigate either steady-state or transient pressures existing in any cylinder or container. General Electric Co., Schenectady, N. Y.

I-342 **Industrial Plating Filters.** Bulletin, 8¾" × 11⅝", 1 page, covers alkaline solution filter for bright nickel, nickel, chrome, copper sulphate, cyanide copper, brass, zinc, cadmium, high speed copper, bright zinc, silver, electrocolor, etc. Industrial Filter & Pump Mfg. Co., 3017 West Carroll Ave., Chicago, Ill.

I-343 **Resistors.** Catalog, 10" × 11", 20 pages, covers line of Koolohm power wire wound resistors, continuously insulated by a special process with a uniform ceramic insulating material; includes chart giving temperature rise at various loads, also mounting dimensions for different types. Sprague Specialties Co., Resistor Div., North Adams, Mass.

I-344 **Combustion Safeguard Systems.** Bulletin No. 96-3, 8¾" × 11½", discusses Protectoglo systems for protection against failure of oil, powdered coal and gas flames; information is included on flame electrode Protectoglo, automatic relite relay and photo electrode Protectoglo, Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-345 **Scientific Laboratory Apparatus.** Catalog 341, 8" × 11", 1216 pages, covers entire line of chemical, metallurgical, physical, clinical, biological and bacteriological apparatus. All requests for this catalog should be directed to manufacturer on company letterhead. Burrell Technical Supply Co., 1935 Fifth Ave., Pittsburgh, Pa.

I-346 **Metal Shielded Wire.** Folder, 8½" × 11", 4 pages, describes and illustrates wire which provides new method of shielding insulated wire or wires with seamless aluminum or copper tubing. Can be made in different combinations from a single conductor with an outside diameter of .018" to multi-cable types up to 1" outside diameter. Precision Tube Co., 3824-26-28 Terrace St., Philadelphia, Pa.

I-347 **"The Hydromike."** Vol. 4, No. 4, 8½" × 11", contains items on level and flow controls and on the Stevens simplified Venturi tube. Leupold, Volpel & Co., 425 N. E. 70th Ave., Portland, Oregon.

I-348 **Tachometer and Vibration Indicator.** Bulletin 1700, 7¾" × 10½", 4 pages, describes and illustrates "Frahm" tachometer for speed measurement and rates of vibration. Also lists mechanical indicating tachometer, chronometric speed indicator, tachoscope and stroboscope. James G. Biddle Co., 1211-13 Arch St., Philadelphia, Pa.

I-349 **Replacement Transformers.** Encyclopedia No. 352-F, 8½" × 11", 32 pages, includes replacements for over 4,000 receivers—power transformers, filter chokes, audio and output transformers. Thordarson Electric Mfg. Co., 500 West Huron St., Chicago, Ill.

I-350 **Electrophotometer.** Folder, 8" × 11", 8 pages, describes and illustrates new a-c. model instrument for colorimetric analysis, includes prices. Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

I-351 **"General Radio Experimenter."** Sept. 1941 issue, 8 pages, contains articles on "The Microflash—A Light Source for Ultra-High-Speed Photography," "Impedance Bridges Assembled from Laboratory Parts — Part III" and list a number of additions to manufacturer's line of instruments. General Radio Co., 30 State St., Cambridge, Mass.

I-352 **Galvanometers for Seismic Recorders.** Folder SG-1, 8½" × 11", 6 pages, describes and illustrates coil galvanometers and 12 channel camera for coil type and oscillograph galvanometers for 6 element cameras. Heiland Research Corp., 700 Club Building, Denver, Colo.

I-353 **Flight Analyzers.** Descriptive and instruction sheets, cover the Nos. 640, 643 and 644 analyzers—640 especially designed to chart altitude of aircraft during flight in terms of barometric pressure, and electrically actuated operations pens record the time during which any particular equipment is used; No. 643 analyzer records air speed, vertical acceleration, altitude and two operations and 644 makes records of information given on the Autosyn system. Julien P. Friez & Sons, Baltimore St. & Central Ave., Baltimore, Md.

I-354 **"The Ohmite News."** Aug.-Sept. 1941, 2 pages, discusses developments of the electric dynamo and arc lamp by Chas. F. Brush; includes items on non-inductive resistors and power tap switches and discusses effect of frequency by resistor impedance. Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago, Ill.

I-355 **Portable Hardness Tester.** Circular F 1689, 3¾" × 8½", 4 pages, describes and illustrates the "Impressor" for testing hardness of metals or plastics after fabrication—aluminum, aluminum alloys and soft metals. Barber-Colman, Co., Rockford, Ill.

I-356 **Photoelectric Colorimeter.** Folder, 8½" × 11", 11 sheets, gives technical information on Lumetron colorimeter, discusses care of instrument and operation, step by step. Photovolt Corp., 95 Madison Ave., New York City.

I-357 **Impulse-Sequence Cycle Controller.** Bulletin No. 575, 8" × 10½", 4 pages, covers controller for tire presses and general time control applications—feature is that time measurement and pilot valve operation are handled separately. The Bristol Co., Waterbury, Conn.

I-358 **Pocket-Size Vibrometer.** Descriptive data 85-910, 8⅜" × 10⅞", 2 pages, describes and illustrates Type JC vibrometer for use in detecting and measuring mechanical vibration in motors, generators and other rotating machinery. Dept. 7-N-20, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

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I-359 **Instrument Charts.** Catalog No. 1230, 8½" × 11" 32 pages, covers 9, 10 and 12 inch mercury and gas-filled ranges and charts, 9, 10 and 12 inch vapor tension ranges and charts, 9, 10 and 12 inch combination charts, 10 inch charts for special applications, 9, 10 and 12 inch pressure-vacuum charts and miniature size charts. C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.

I-360 **Salt Spray Corrosion Test Equipment.** Bulletin, 8½" × 11", 2 pages, describes and illustrates equipment designed to determine the corrosion resisting qualities of electroplated or coated metal, alloys, metal parts, lacquered or pointed samples, etc. Industrial Filter & Pump Co., 3017 West Carroll Ave., Chicago, Ill.

I-361 **Control Equipment.** Price Sheets F-1612-4, 1636-2, 1637-2 and 1660-1 TC, each 8½" × 11", describe and illustrate control motors for 2-position, floating and proportioning control; motor-operated valves, V-ported, for floating and proportioning control; and motor-operated sanitary valves, 2-position-reversing-proportioning. Barber-Colman Co., Rockford, Ill.

I-362 **Photoelectric Fluorescence Meter.** Folder, 8½" × 11", 14 pages, is devoted to discussion of technical information concerning the Lumetron fluorescence meter. Photovolt Corporation, 95 Madison Ave., New York City.

I-363 **Recorders and Automatic Controllers.** Bulletin No. 548, 8" × 10½" 12 pages, describes and illustrates instruments for application to industrial furnaces, kilns and ovens, used with gas, electric and oil. The Bristol Co., Waterbury, Conn.

I-364 **Broadcast Transformers.** Catalog No. 500-F, 8½" × 11", 20 pages, covers line of incher, bantam, multi-shield bantam and major series audio transformers, filters, line equalizers, driver transformers, high level modulation transformers, modulation reactors, filament and plate transformers, filter reactors and power transformers. Thordarson Electric Mfg. Co., 500 West Huron St., Chicago, Ill.

I-365 **Midget Magnetic Relays.** Bulletin 106, 8" × 10½", 2 pages, covers relays for use on a-c. or d-c. and can be equipped with single- or double-pole and single- or double-throw contacts. Standard relays are of the open type mounted on a molded insulating base. Ward Leonard Electric Co., 38 South St., Mount Vernon, N. Y.

I-366 **"C-D Capacitor."** Vol. 5, No. 8, 16 pages, contains articles on "Filter Design"—design and characteristics of low- and high-pass filters and "Antennas for FM." Cornell-Dubilier Electric Corp., New Bedford, Mass.

I-367 **Moisture Control System.** Bulletin 212-2, 8½" × 11", 16 pages, describes and illustrates "Verigraph" system which measures and controls the equilibrium moisture content of the paper web during manufacture. The Foxboro Co., 46 Neponset Ave., Foxboro, Mass.

I-368 **Hot Water Heating Control.** Folder, 8" × 11", 6 pages, describes and illustrates pneumatic and electric "Duo-Stat" regulators for automatically maintaining the proper relationship between the outdoor temperature and the temperature of the heating system. Johnson Service Co., Milwaukee, Wis.

I-369 **"The Laboratory."** Vol. 12, No. 5, 6" × 9", 24 pages, contains article entitled "The Birth of Modern Chemical Nomenclature"; also items on new electric water bath, Aerosol—new wetting agent, ultraviolet lamp for laboratory, slide heater and other devices for laboratory use. Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

I-370 **Thermometer and Pressure Gage Accessories.** Catalog No. 6706-A, 8" × 10½", 24 pages, shows bulbs, tubing extension necks, separable sockets, wrought iron sockets and fittings, wet- and dry-bulb assemblies, pulsation checks, oil seals, gage cocks, charts, etc. for manufacturer's line of thermometers and pressure gages. The Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

I-371 **Precision Test Equipment.** 1942 Catalog, 8½" × 11", 16 pages, describes and illustrates vacuum-tube multi-range testers, "Electronamic" tube testers, "Electronamic" tube and battery testers, volt-ohm-decibel-milliammeters, multi-range a-c. ammeter and industrial a-c.-d-c. circuit testers, signal generators, etc. Precision Apparatus Co., 647 Kent Ave., Brooklyn, N. Y.

I-372 **Multiple-range Hand Tachometer.** Bulletin, 8½" × 11", 1 page, describes and illustrates tachometer (in carrying case) of centrifugal type, designed to fit in palm of hand and weighing about one pound. Dial is approximately 4" in diameter and has three ranges. Jones-Motrola Sales Co., 432 Fairfield Ave., Stamford, Conn.

I-373 **Aircraft Instrument Test Apparatus.** Bulletin, 8½" × 11", 2 pages, shows turn indicator test stand, oscillating table, special manometer for testing of aircraft engine manifold pressure gages and special portable manometer for testing airspeed indicators. Ideal Laboratory & Supply Co., P. O. Box 193, Cheyenne, Wyoming.

I-374 **Timing Devices.** Catalog Sheets 40-A-1 to A10, 8½" × 11", 10 pages and price list, covers line of portable switches, wall switches, coin meters, bell signals and switches and industrial switches for built-in applications. M. H. Rhodes, Inc., 30 Bartholomew Ave., Hartford, Conn.

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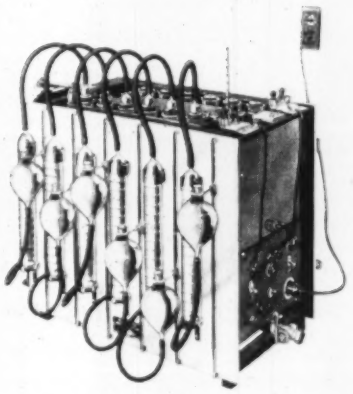
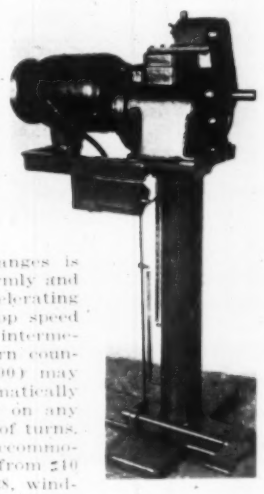
Originated in Fleischmann Laboratories, Standard Brands, Inc., new instrument offers a means of determining thiamine (vitamin B_1) by speedy, simple and accu-

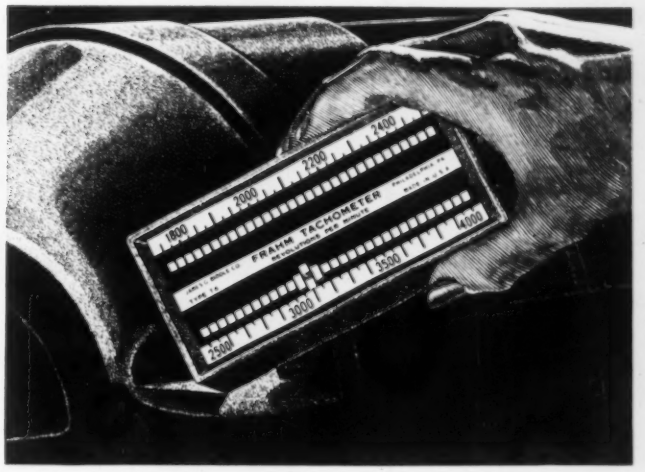


rate yeast fermentation method. Fermentometer can be applied successfully to all foods, many biological fluids, plant and animal tissues, metabolic studies, etc. Five different or similar samples and the control can be run simultaneously. Complete fermentation tests can be made in three hours by persons who need not have technical knowledge. It is only necessary to prepare a fine suspension or solution of the sample in water, add necessary reagents, and place sample in the Fermentometer. After a specified time, volume of gas generated within the gasometer assemblies is read and thiamine content computed.—*American Instrument Co., 8010 Georgia Ave., Silver Spring, Md.*

Combination Universal Coil Winders

New Combination Universal Coil Winder allows high-speed winding driven directly from the motor shaft; or high torque at lower speeds driven through a back gear arrangement. Selection between these may be made by shifting a lever on the gear head. A foot pedal synchronizes the control of the brake, motor switch and variable speed. Thus simple control of speed through either of the speed ranges is obtained; uniformly and steplessly accelerating from start to top speed or any desired intermediate speed. Turn counter (up to 10,000) may be set to automatically stop the winder on any desired number of turns. Machine will accommodate wire sizes from #40 to as large as #8, winding them into coils as large as 8" in diameter and 8" long, at speeds up to 5000 rpm. "These characteristics keep this machine always ahead of the operator, and act as a challenge, assuring a maximum production." Direct-drive and back-gear are available when the combination is not required.—*Globe Tool & Engineering Co., Dayton, Ohio.*





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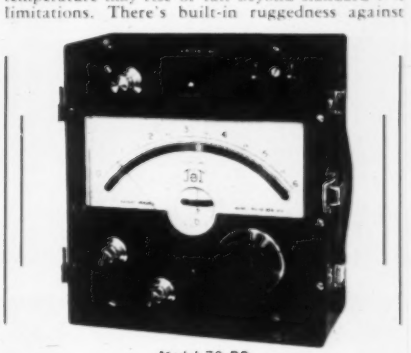

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INSTRUMENTS' BOOK SHELF

Instrument Flying. By P. V. H. WEEMS and CHARLES A. ZWENG. Weems System of Navigation, Annapolis, Md., 1940. Leatherette, 6 × 9¼ inches, iv + 328 pages. Price $4.60.

Most noticeable and distinctive feature of this book is the large type—which seems to be what is technically known as 12-point Benedictine with 2-point leads. There are five lines to the inch and—as a rough guess—not more than 70,000 words in the entire book.

It is a carefully prepared text for serious students. The authors designed it specifically "with a view to meeting the requirements for the U. S. Government instrument rating. In order to assist the student preparing for written examinations, numerous typical questions with answers are given at the end of the book. The answers to these questions are, of course, a condensed repetition of the text in the body of the book, and in some cases, the questions and answers overlap other questions and answers, but the student should be able to judge when he is sufficiently prepared by reference to the quiz section after completing his study of the text."

The authors purchased the rights to Howard Stark's *Instrument Flying*, which was a history-maker but unfortunately was allowed to fade almost into oblivion after 1936 when the brave Stark met his death while walking through a snowstorm from a forced landing in the Rocky Mountains . . . carrying his airplane compass in an effort to reach civilization by foot without swerving from the course!

As the title implies, this work deals with uses of instruments, rather than with the instruments themselves, but instrument characteristics are thoroughly analyzed. The limitations of each type of instrument are set forth; the sources of error explained; and even the notes on instrument maintenance are by no means scanty.

In addition to chapters on instruments and their uses, there are five chapters on meteorology; others on Civil Air regulations, etc., and useful appendices. The illustrations deserve special commendation. Not only are the diagrams reproduced with all lettering easily legible, but the larger illustrations, such as maps, are printed on folded inserts.

As many readers know, Lieutenant-Commander Weems is the author of *Air Navigation* and other works; and Mr. Zweng, an instructor in the U. S. Air Corps, is the author of *Radio and Instrument Flying* and other works. In their preface they name five individuals, as well as instrument companies and government agencies, as deserving credit in connection with the preparation of this book. All in all, the result is a credit to the late Howard Stark and to all who have collaborated. —M. F. BEHAR

Aircraft Instruments, Their Theory, Function and Use. By ORION EDWARD PATTON. D. Van Nostrand Co., New York, 1941. Cloth, 6¼ × 9¼ inches, x + 220 pages. Price $2.75.

To the best of the reviewer's knowledge, this book deals with a greater variety of devices than any of the previous books on aircraft instruments. Not only does it describe every class and type and variety of instrument utilized on American aircraft as of late 1940 (the preface is dated January 1941) but it includes descriptions of such devices as oxygen-regulating systems, illuminating systems, pumps and other such devices, the maintenance of which is (or may be) placed in the hands of instrument men.

The author is an aircraft instrument technician and instructor in the U. S. Army Air Corps and is also the chief instructor in the Harrisburg Evening School connected with the Pittsburgh Institute of Aeronautics. He has wisely used his official connections to the advantage of the student of the book in obtaining data from various official and commercial sources. So numerous are the individuals and organizations listed in his preface that this list takes more than one page. As the author himself says, "While the book is a personal effort, it is also in a sense a coöperative effort . . ." We repeat that this is to the benefit of the reader of the book.

Nevertheless, we cannot agree with all the statements made in the highly complimentary foreword by a Civil Aeronautics Board official. For example, it is not true that the discussion of each instrument is "complete." Many descriptions are so brief as to be inadequate. In some cases there are mere mentions rather than descriptions.

What has not been skimped is the explanation of the underlying principles. The elements of thermometry, electricity, magnetism, hydrostatics, barometry, and other basic engineering subjects are presented in order that the operation of each class and type of instrument may be better understood by beginners. From the emphasis on elementary physics, etc., and the apparently intentional avoidance of "fine points," it is evident that the book is designed primarily for readers such as the author is teaching in his Defense courses.

It is to be regretted that the photographs (of which there are more than a hundred) are *all* indistinct and muddy by being printed on uncoated paper. It came as a shock to see such poor quality of reproductions in a book bearing the famous imprint of one of the world's greatest technical publishing houses. Some of these half-tone illustrations are mere blurs in which details are entirely lost. Likewise below Van Nostrand standards is the fact that so many errors have got by the editors and proof-readers—errors such as wrong connections in electrical diagrams, textual reference to diagram details which are not there, as well as plain typographical errors. However, the alphabetical index has evidently been prepared with loving care and thoroughness—which is rather exceptional in recent books pertaining to aviation, and hence a pleasant surprise!

This book is far superior to several other aircraft instrument books which have been brought out in recent years. All in all, the reviewer believes that in some respects no other aircraft instrument book is better and he is certain that none is more comprehensive. —M. F. BEHAR

Electromagnetic Devices. By HERBERT C. ROTERS. John Wiley & Sons, Inc., New York, 1941. Cloth, 6" × 9¼", vi + 561 pages. Price $6.00.

A large proportion of instrument men (and by "large" I dare say about three out of five of those holding responsible positions) will welcome this first thorough treatment of *practically all types of non-rotary* electromagnetic devices. These are the devices which play important roles in modern instrumentation and which seem to have been neglected—at least in comparison with electrical "machinery."

The author is at present Director of Research of the Fairchild Aviation Corporation but he had taught this particular subject for years to graduate students at the Stevens Institute of Technology where he was Assistant Professor of Electrical Engineering. It was there, in 1932, that he undertook this work at the suggestion of Dr. Alan Hazeltine, then head of the Department of Electrical Engineering at Stevens, whom he credits with originating some of the methods of magnet design presented in this book.

We must hasten to add that the practical point of view permeates the entire book, many of the original problems and methods used in the latter chapters being an outgrowth of the author's consulting practice.

Having intended his work not only as a reference book for engineers but as a textbook for graduate students in electrical engineering, the author has followed the custom of putting a number of problems at the ends of most chapters, but he has departed from the custom of giving fanciful problems: his problems are evidently taken from actual practice.

After Chapter I, which is a brief introduction to the subject, there is a sixty-page chapter on the properties of magnetic materials which, in the reviewer's opinion, is the outstanding feature of the book. It is unlikely that so many data on magnetic properties have ever been assembled and presented so conveniently. The curves and tables are up-to-the-minute; and many of them are given for the first time. There is a profusion of bibliographical references.

Chapter III, on the theory of operation of electromagnets, discusses the complex factors which enter into design and discusses particularly the desirable and undesirable energy changes.

Chapters IV and V treat, respectively, the calculations of magnetic circuits and of air path permeance. In both of these chapters the author includes easily-understood worked-out examples of the rational methods which were devised by Dr. Hazeltine and himself.

The remaining nine chapters deal mostly with practical problems of design, as follows: VI. Coils. VII. Heating of Magnet Coils. VIII. Magnetic Forces. IX and X. Tractive Magnets. XI. Time-delayed Magnets. XII. High-speed Magnets. XIII. Alternating-current Magnets. XIV. Relays. In these nine chapters the worked-out examples of rational design are almost equivalent to visiting the author and his associates and seeing them at work: part of the work consists in the immediate use of applicable formulas; part of it involves trying out this-and-that; part of it involves searching for the material that comes closest to the optimum . . . and so on. It's the real thing! And always, Roters reminds the reader that certain factors have to be kept in mind and that some are more important than others. The prediction may be ventured that these chapters will begin influencing designs immediately, so that the improvements in commercial products will be visible by 1942 or 1943.

The book concludes with a carefully compiled index, the thoroughness of which may be judged from the fact that it occupies 28 pages. This index will help those who will use the book as an authoritative reference in making decisions as to classes and types of equipment to be selected rather than to be designed. —M. F. BEHAR

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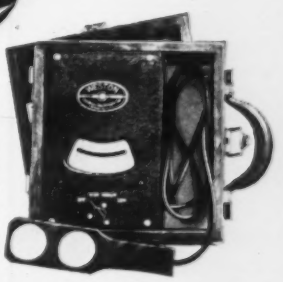

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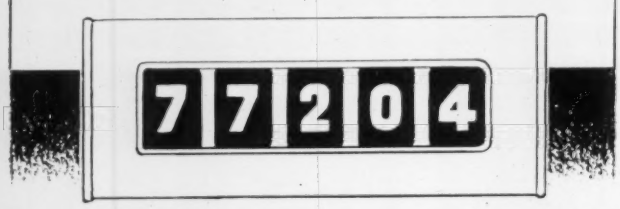

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Instruments
THE MAGAZINE OF Measurement and Control

Vol. 14 NOVEMBER 1941 No. 11

FRONT COVER: Some of the instrumentation in the Dep't of Metallurgy, Notre Dame University. At the far end, furnaces in which specimens have been held at constant temperature for two years.
Courtesy Prof. E. G. Mahin, Head Dep't of Met.

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Level Control, the Cinderella

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